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Analysis of Requirements for Accelerating the Development of Geothermal Energy Resources in California

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C. D. Fredrickson

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Department of Energy
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California Institute of Technology
Pasadena, California

This report was prepared by the Jet Propulsion Laboratory, California Institute of Technology, for the Department of Energy, Division of Geothermal Energy and the California Energy Resources Conservation and Development Commission (CERCDC), Alternatives Division under an agreement with the National Aeronautics and Space Administration.

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PREFACE

The work described in this report was performed by the Regional Operations Research and Systems Analysis for Geothermal Energy Development Task of the Jet Propulsion Laboratory.

FOREWORD

Geothermal energy has the potential of contributing significantly to the Nation's energy needs in the post 1985 period. This is particularly true for California where the United States Geologic Survey (USGS) has identified hydrothermal resources equivalent to 19 large, 1000 MW_e power plants. The hot dry-rock resources could ultimately prove to be an even larger power source. It is expected that increased resource assessment and exploration activities over the next several years will add substantially to the States currently identified geothermal potential.

Even though there are numerous examples of the utilization of geothermal applications around the world and in the United States, the commercial use of geothermal energy, for the most part, does require much "new technology". As such, its use in the United States poses significant technical challenges and environmental and socio-economic uncertainties which must be faced and resolved before large-scale geothermal energy development can proceed.

The California Energy Resources Conservation and Development Commission (CERCDC) and the Department of Energy (DOE) are both vitally interested in the establishment of a viable geothermal energy option in the State and in the Nation. To this end, the Energy Commission and DOE have jointly sponsored "Regional Operations Research for Geothermal Energy Development in California" directed at identifying the type, magnitude, and schedule of Governmental (Federal, State and local), public, and industrial actions needed now and in the future to assure the timely development of the State's geothermal energy resources.

The first year's effort of the DOE/CERCDC Regional Operations Program focussed on the use of the hydrothermal geothermal resources for generating electric power. In implementing the program JPL adopted a two-phased, goal oriented, approach. (See Appendix A for description.) First, power development projections (scenarios) were prepared for various high-potential geothermal prospects in the states. These scenarios were based on the development status data contained in the Energy Commission's document "Geothermal Energy Resources in California: Status Report"* and from discussions and reviews with the members of three advisory panels representing industry, federal and state agencies, and local communities (Appendix C). The scenarios serve as the basis for formulating geothermal energy development plans that can be achieved through the concerted efforts of those in the state responsible for geothermal energy development and with the support of the federal geothermal energy research, development and demonstration program.

*"Geothermal Energy Resources in California: Status Report Jet Propulsion Laboratory Document 5040-25, prepared for the California Energy Resources Conservation and Development Commission, Research and Development Division, Pasadena Ca., June 30, 1976.

During the second phase of the JPL effort the schedule-related near-term (i.e., through 1990) development activities were defined and program recommendations were formulated based on an analysis of the critical economic technical, and institutional factors associated with each of the scenarios.

The report is divided into three sections.

I. Introduction and Background

II. Regional Geothermal Development Program Requirements

III. Subregion Geothermal Development Program Requirements

Section I discusses the potential role that geothermal energy can play in meeting California electrical energy needs and the committment required to fulfill that role. Section II presents programmatic recommendations, common to most of the State, for making geothermally generated electrical power competitive with other sources of energy and to facilitate the regulatory, permitting, and leasing process. Section III presents the rationale and activity schedule for each scenario and a summary of recommended actions by subregion to stimulate the postulated growth.

In the JPL analysis the state was divided into the five geothermal resource subregions as depicted in Figure 1. While the report addresses the identified needs of each of the five subregions the early development emphasis is primarily on the Geysers and in the Imperial Valley subregions. This should not be interpreted to mean that the other subregions of the state are not as important. On the contrary the geothermal resources in these subregions could prove to be much larger than those at either the Geysers or in the Imperial Valley and are expected to contribute significantly to the state's energy needs beginning in the mid 1980's. Instead the emphasis in the report is merely a reflection of the high industrial interest, better market definition, and more advanced state of development and knowledge of the geothermal resources in the Geyser and Imperial subregions. Because of this recognized limitation, it is recommended that the follow-on regional operations research activities of the CERCDC and DOE address the special development considerations of the Eastern Sierra and Northeast subregions of the state more fully including:

(1) Resource confirmation.

(2) Market identification.

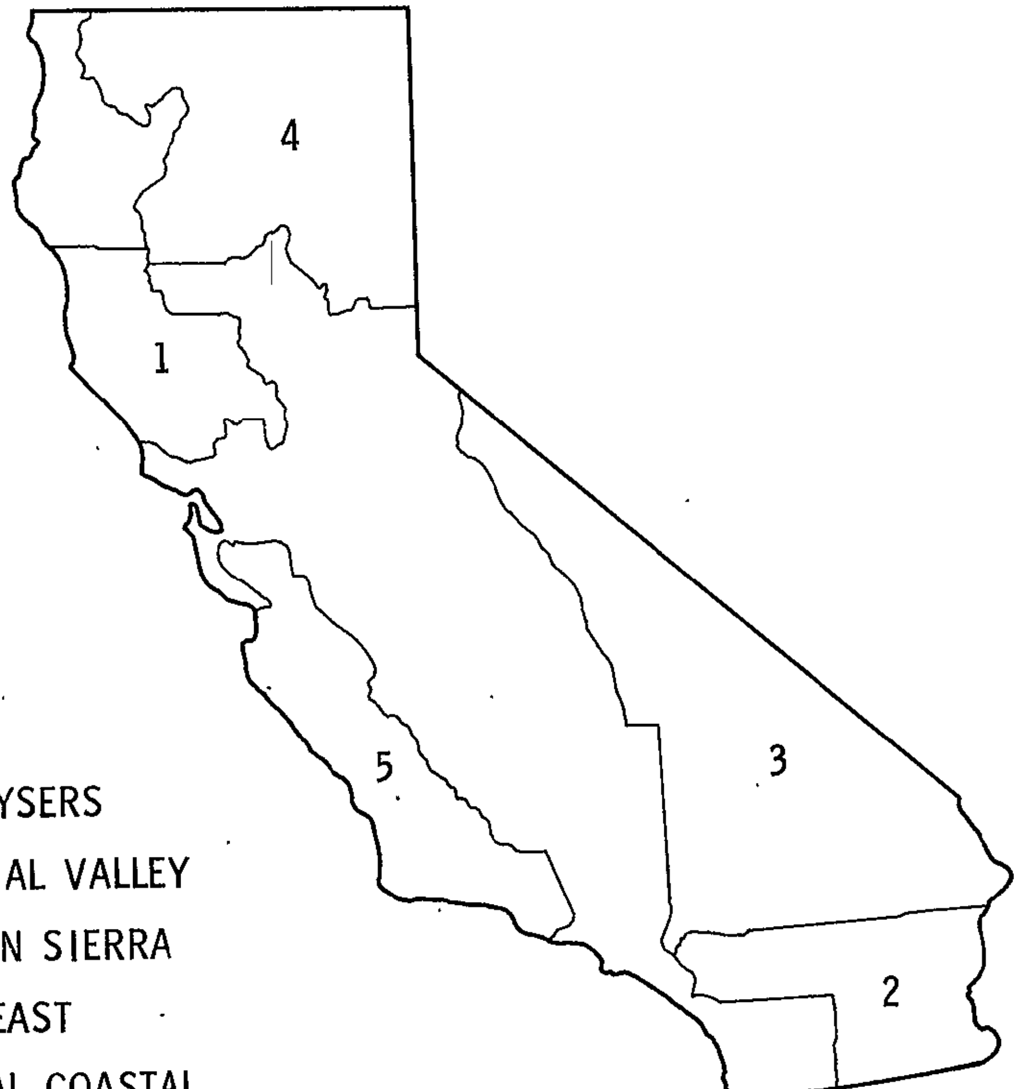
(3) The effect of transmission line availability and costs on resource development.

More effort is also required to assess and encourage the development of the diffuse but potentially large non-electric application market for geothermal energy in the state.

NEPA	National Environmental Policy Act
OPR	Office of Planning and Research (Calif.)
OPS	Operations Plan
"P"	Proposed Action Approval
PG&E	Pacific Gas and Electric Company
PPL	Pacific Power and Light Company
PUC	Public Utilities Commission (Calif.)
RWQCB	Regional Water Quality Control Board (Local)
SDG&E	San Diego Gas and Electric Company
SCE	Southern California Edison Company
SMUD	Sacramento Municipal Utility District
SPP	Sierra Pacific Power Company
SVEC	Surprise Valley Electrification Corporation
USGS	United States Geological Survey
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service

ABSTRACT

Various resource data are presented showing that geothermal energy has the potential of satisfying a significant part of California's increasing energy needs. General factors slowing the development of geothermal energy in California are discussed and required actions to accelerate its progress are presented. Finally, scenarios for developing the most promising prospects in the state directed at timely on-line power are given. Specific actions required to realize each of these individual scenarios are identified.



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1. THE GEYSERS
2. IMPERIAL VALLEY
3. EASTERN SIERRA
4. NORTHEAST
5. CENTRAL COASTAL

Figure 1. Geothermal Subregions of California

DEFINITION OF ABBREVIATIONS

AFC	Application for Certification
APCD	Air Pollution Control District (local, Calif.)
ARB	Air Resources Board (Calif.)
BLM	Bureau of Land Mangement
BUR	Bureau of Reclamation
CDWR	California Department of Water Resources
CERCDC	California Energy Resources Conservation and Development Commission
CEQA	California Environmental Quality Act
CPU	California Pacific Utilities
DIR	Department of Industrial Relations (Calif. OSHA)
DFG	Department of Fish and Game (Calif.)
DOG	Department of Oil and Gas
EAR	Environmental Analysis Report (Federal)
EIR	Environmental Impact Report (CEQA)
EIS	Environmental Impact Statement (NEPA)
EPA	Environmental Protection Agency (Federal)
EPRI	Electric Power Research Institute
DOE	Department of Energy
GCTF	Geothermal Component Test Facility
GLEF	Geothermal Loop Experimental Facility
GRC	Geothermal Resource Council
GRIPS	Geothermal Resource Impact Projection Study
IID	Imperial Irrigation District
KGRA	Known Geothermal Resource Area
LADWP	Los Angeles Department of Water and Power

CONTENTS

APPENDICES

Figures

Tables

SUMMARY

California geothermal resources have the potential of playing a major role in meeting the State's growth requirement for electrical energy after 1985. Analyses of the potential of geothermal power development in several known resource areas demonstrate the feasibility of generating up to 20,000 MWe of new energy by the year 2000. To realize the power production projection in a timely manner, it will be necessary to: streamline the federal, state, and local leasing and regulatory processes; make hot-water power generation economically feasible through tax incentives and new or improved technology; to build commercial utilities confidence in the process through commercial scale demonstration plant; and to resolve specific issues in a timely manner.

A. THE POTENTIAL ROLE OF GEOTHERMAL ENERGY (FROM SECTION I)

Based on United States Geological Survey (USGS) geothermal resource assessment data and industrial development interest and activities, California has a large geothermal energy development potential which could satisfy a large portion of the State's post-1985 growth in electrical demand. The significance of this potential geothermal option is illustrated in Figure S-1 which shows a projection of the State's new base-load electrical power requirements through the year 1995 and the composite of 13 specific-prospect scenarios for geothermal energy development in known resource areas. The scenario energy projections clearly indicate the significant impact of the State's potential geothermal energy option. The timely realization of the scenarios are based on the assumption of:

(1) Full development of the Geysers steam field by 1985.

(2) Commercial power plant development in the Imperial Valley in the early 1980's.

(3) Increased leasing of federal lands (particularly in the Eastern Sierra, Northeast and Geysers subregions) followed by exploratory drilling to discover and prove those geothermal resources necessary to the significant growth in the post-1985 time period.

It is important to realize that the scenarios are not projections or predictions of what <u>will</u> naturally occur but of what potentially <u>can</u> occur providing the state and federal governments take the steps necessary to encourage and facilitate environmentally acceptable geothermal energy development in the state.

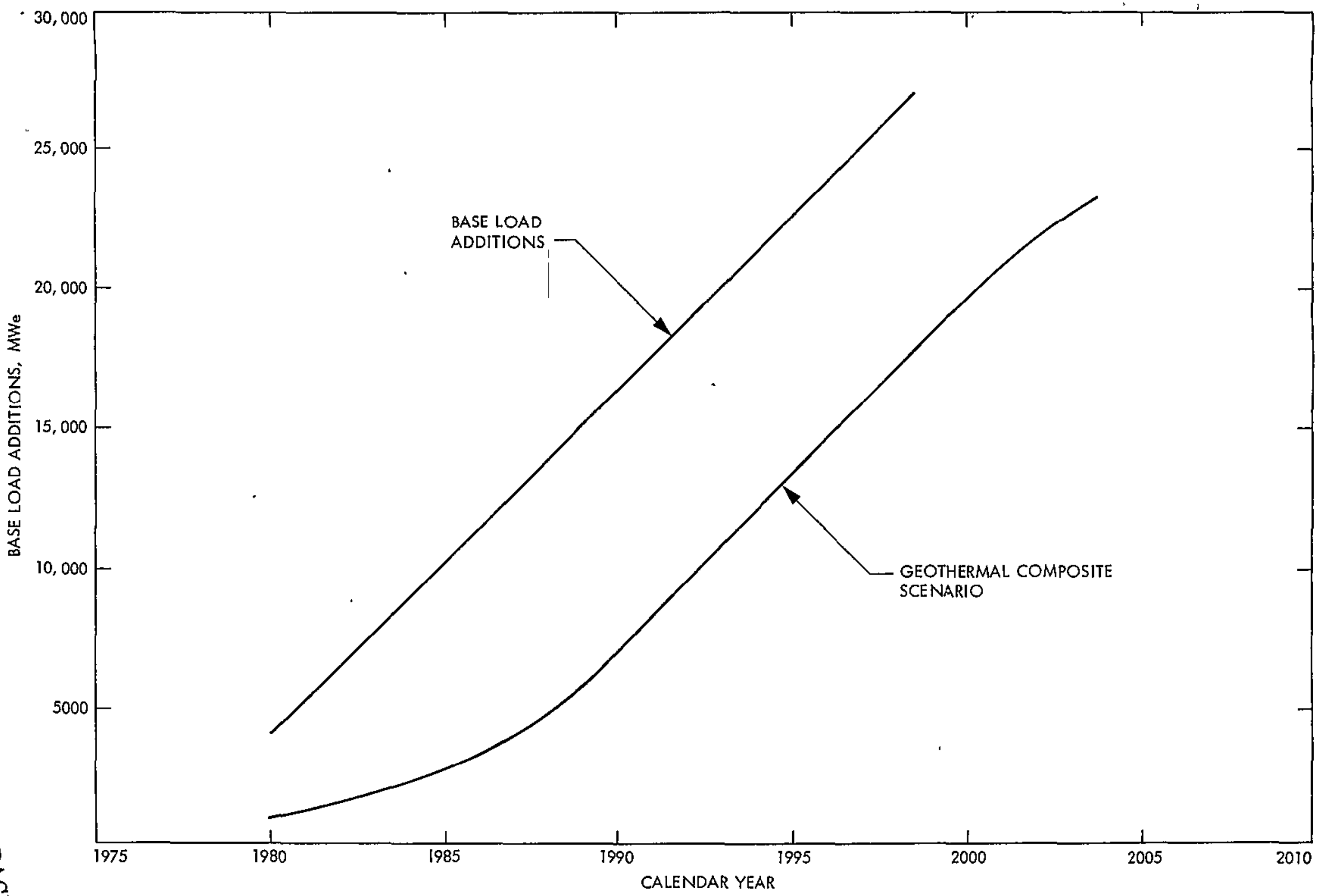

Figure S-1. Potential Contribution of Geothermal Energy to California's New Base Load Additions

B. FACTORS IMPACTING FULL AND TIMELY DEVELOPMENT

Full implementation of the scenarios in a timely manner consistent with projected energy needs requires the understanding and solution of several problem areas that currently affect geothermal energy development:

(1) While there is ample scientific evidence that a large geothermal potential exists, only a small fraction has been commercially confirmed by deep exploratory drilling.

(2) Only the Geysers steam field is currently commercially producing power. Environmental requirements have slowed full development of the steam field.

(3) The regulatory permitting process consumes almost one-half of the approximately 9 years required to complete a power plant. This lengthening of the development process not only impacts the timeliness of meeting the nation's growth in energy needs but adds significant additional economic burden to the commercial developers.

(4) The utilities and exploration companies lack confidence to commit to full commercial development of hot-water resources. Both the commercial competitiveness of the resultant power and the reliability of plant operation are in question.

In addition to these four widely applicable factors, there are prospect-specific issues that need to be resolved in a timely manner if each of the scenarios are to materialize. Figure S-2 presents a summary of the resource development status for the thirteen prospects in the state covered in this report and the key issues facing each.* (The "Additional" category provides for the development of other prospects not specifically identified in the first twelve.) As is evident from the figures, only units 1-15 of the Geysers steam field are not paced by the resolution of technological, economic, environmental, or institutional issues.

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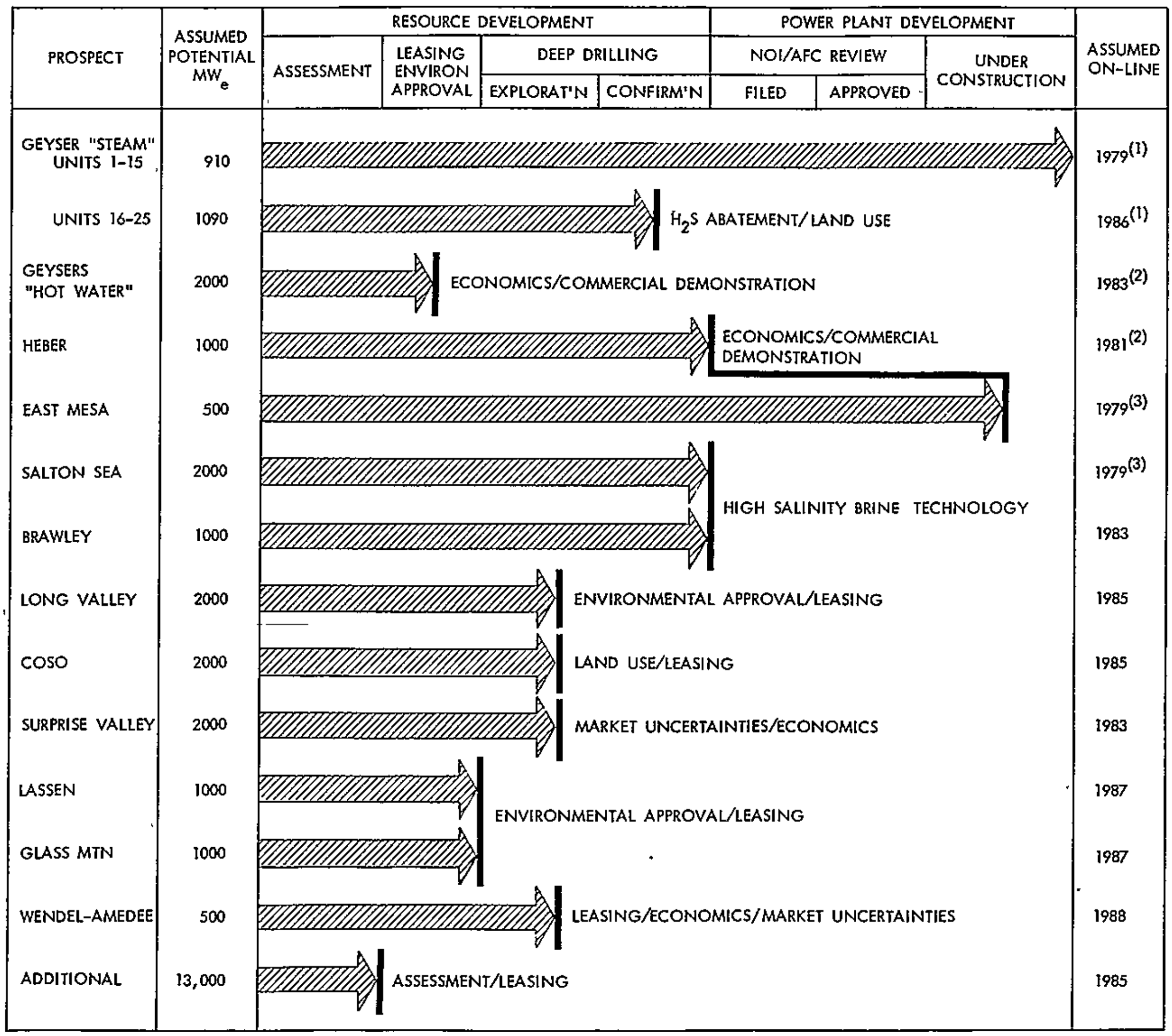
*The cross-hatched arrows indicate the development process for each prospect through the various stages of resource and power plant development. Except as noted, the year at the right of the figure is the date assumed for the first plant on line for the various prospects <u>provided</u> the identified key issues are resolved.



(1) DATE LAST PLANT ON-LINE
(2) COST SHARED DEMONSTRATION
(3) PILOT PLANT

Figure S-2. Summary of Resource Status in California

C. PROGRAM STRATEGY FOR ACCELERATING PROGRESS AND REALIZING SCENARIO POTENTIAL

Since geothermal development outside of the Geysers steam field is limited and it now takes on the order of 9 years to complete the first plant on a given prospect, the main contribution through 1985 will be from the Geysers steam field. Post-1985 growth will have to be based on the use of the more abundant hot-water resources. Because of the long lead time associated with resource exploration and power plant development, post-1985 growth is dependent on increased actions and commitments of the exploration companies and utilities in the late 1970's and early 1980's. The actions summarized below are aimed at implementing the scenario projections by overcoming the prospective development schedule delays and economic impacts.

(1) Expedite a timely full development of the Geysers steam field (discussed as a subregion below.)

(2) Accelerate and encourage exploration to develop new prospects and to confirm projected prospects through: speeded-up federal leasing, streamlined environmental review and permitting for exploratory wells, and tax incentives to reduce exploration costs and risks.

(3) Stimulate commercial utility commitment by facilitating in a timely manner the construction of a cost-shared commercial-scale demonstration plant(s) to reduce and understand hot-water power plant performance uncertainties.

(4) Make hot-water power commercially competitive by appropriately scheduled technology developments and by tax incentives (or their equivalent).

(5) Assist state and federal regulatory agencies in maintaining appropriate environmental and other controls with an expeditious procedure, thus protecting public and governmental concerns but expediting power development in a timely and economic manner.

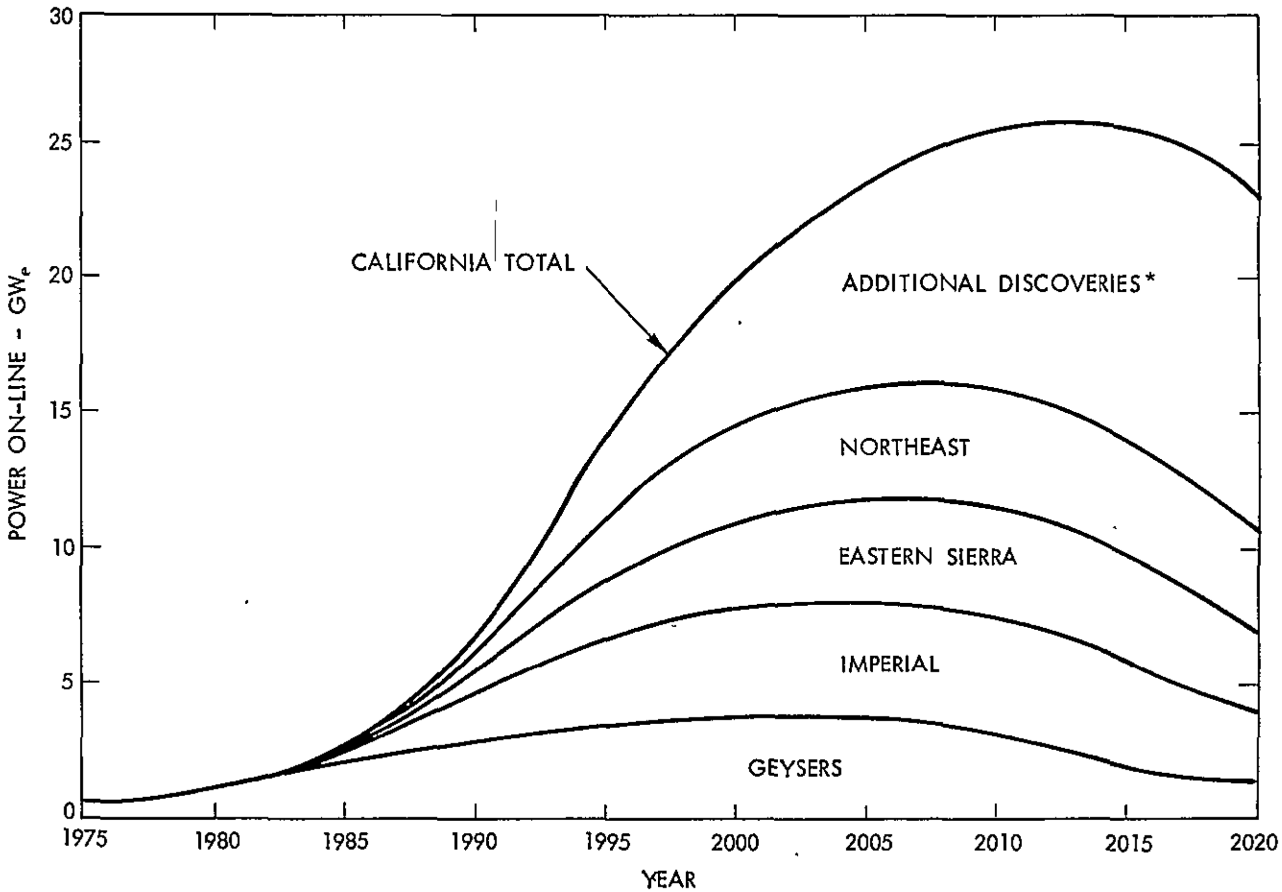
D. SUBREGION PROGRAM REQUIREMENTS

Figure S-3 shows the potential contribution of the various resource subregions of the State. The programmatic actions required to resolve the key issues associated with the postulated scenarios are listed below by subregions.

(1) <u>The Geysers Subregion (from Section IIIA)</u>

(a) Steam Field

The commercial viability of the steam resources is well established. Utility interest is high. However, in the past several years development has been slowed



*INCLUDES CENTRAL COAST SUBREGION

Figure S-3. California Subregional Geothermal Growth Scenarios

by the implementation of the California Environmental Quality Act (CEQA) and by H_2S air emission problems. The required key programmatic actions include:

- Successful development and demonstration of H_2S abatement technology by January 1979.

- Support of the local air pollution control districts to monitor emissions from existing plants and development standards for new plants by 1979.

- Support of the four counties in gathering the environmental data necessary for development approval by 1979.

- Permitting project to facilitate intergovernment (federal, state, local) coordination, establish standards, and develop procedures for streamlining the environmental review and permitting process by October, 1979.*

(b) Hot Water Fields

While the potential of the hot water resources in the Geysers subregion is believed to be large based on the numerous hot springs in the area, very little is known of either its extent or temperature. For the scenario a temperature of 200°C was assumed. The current estimated cost of power ranges from 46 to 62 mills/kWh primarily the result of high drilling costs. The development of the hot water resources would be expected to benefit from those actions taken in support of the full development of the steam field. However, the following additional actions would be required to establish the commercial viability of the hot water resources by the mid 1980's.

- Tax incentives (intangible drilling cost and depletion allowance) by 1978 to encourage exploration.

- Expanded resource assessment in 1978-80 to facilitate planning in the subregion.

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*The Permitting Project's scope would include all the subregions of the state. However, the Geysers is one of the more critical subregions at this time.

- A shared-risk, demonstration plant, to reduce performance uncertainties by 1983.*

- Technology programs to reduce drilling costs, improve well flow and increase plant efficiency by 1985.

- Leasing of the outlying KGRA's Knoxville, Little Horse Mountain, Witten Springs, and Lovelady Ridge beginning in 1984.

(2) The Imperial Subregion (from Section IIIB)

(a) East Mesa and Heber

East Mesa and Heber are both proven resources with temperatures near 190°C and salinities less than 14,000 ppm. The current estimated bus bar cost of power ranges from 40 to 46 mills/kwhr. The costs are dominated by both the enthalpy of the fluid and the lower resulting plant efficiency. Magma is constructing a pilot plant (non-commercial) at East Mesa. San Diego Gas and Electric is proposing a shared-risk demonstration plant at Heber. Both plants are based on binary cycle technology. Republic Geothermal is considering a flashed steam plant at East Mesa. The following actions are required to establish the commercial viability of these resources:

- Continuation of the loan guarantee to support reservoir confirmation at East Mesa.

- Tax incentives by 1978 to encourage resource development.

- Continued support of the hydrocarbon turbine and down well pump technology critical to the proposed demonstration plant.

- Shared-risk demonstration plant at Heber by 1981 to reduce performance uncertainties.

- Advanced technology programs to improve well flow and increase plant efficiency necessary to reducing the cost of power by 1982.

- Further investigation of the long-term cooling water availability in the subregion.

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*The need for the demonstration plant may be satisfied by similar plants proposed at Roosevelt Hot Springs and Valles Caldera (see Section IIB).

(b) Brawley and Salton Sea

Brawley and the Salton are both proven sources with temperatures greater than 250°C but of very high salinity. The salinity at the Salton Sea is 220,000 ppm and that at Brawley is 90,000 ppm. The estimated cost of bus bar power ranges from 33 to 45 mills/kWh which makes it potentially quite attractive providing the technical problem associated with the high saline brines are resolved.

A flashed steam binary cycle test loop, known as the Geothermal Loop Experimental Facility (GLEF) is in operation at Niland with promising results. The following additional actions are required to bring these resources on line:

- Tax incentives in 1978.
- Conversion of the GLEF to a 10 MW_e pilot plant by 1979.
- Continued support of the development of the flashed steam-binary cycle technology by 1981.
- Establishing of a well completion and extraction technology test facility development of the technology to increase well life and sustain high flow rates with these highly saline brines by 1981.
- Continued brine chemistry research by 1983 to improve plant reliability and availability.

(3) <u>The Eastern Sierra Subregion (from Section IIIC)</u>

The Eastern Sierra potential contains two of the largest identified geothermal resources in the state at Long Valley and at Coso Hot Springs. However, the existence of the resources generally <u>has not been proven</u> by deep drilling. The temperature of the resource has been assumed to be 220°C and, if so, could probably use existing flashed steam technology. The estimated current cost of power ranges from 42 to 55 mills/kWh; dominated by high drilling costs. Development of the resource would be expected to benefit from the demonstrated plant and the technology program proposed for the Geyser hot water resources. The lands associated with these resources at Long Valley and Coso are primarily under the control of the U.S. Forest Service and the Navy respectively. Very little leasing has occurred and it now is the critical factor constraining the rate of development. Industry interest is high for both resources. Transmission line availability could limit initial development.

The critical actions to facilitate development (in addition to technology) are:

- Tax incentives in 1978 to encourage exploration.
- Leasing of "grandfather rights" land in Long Valley by April 1978.
- Leasing of the Navy lands at Coso by November 1978.
- Further analysis of transmission line availability in the Eastern Sierra and the impact on power costs by the end of 1978.
- Permitting project to facilitate further leasing and environmental approval in the subregion by the end of 1979.

(4) The Northeast Subregion (from Section IIID)

Most of the development activity to date in the subregion has centered on Surprise Valley and Wendel-Amedee. Both have been demonstrated to be lower temperature (i.e., 175°C) with current power cost estimated to range between 54 and 71 mills/kwhr. If so both will require significant advancement in utilization and extraction technology to make them competitive. Two promising but unproven resources have been identified at the Lassen and Glass Mountain KGRA's with estimated cost ranges of 42 to 55 and 46 to 62 mills/kwhr respectively; both are dominated by high well costs. Leasing is planned at Wendel-Amedee and Glass Mountain. Currently, there are no leasing scheduled at Lassen. Generally, there is high industrial interest in the resources in the subregion. Transmission line availability could be an issue. The action required to encourage development are presented below.

(a) Surprise Valley and Wendel-Amedee.

- Tax incentives in 1978.
- Leasing of BLM lands at Wendel-Amedee by 1981 (could be completed in 1978).*
- Technology developments to reduce drilling costs and improve well flow by 1983.
- Advanced binary (or perhaps total flow) technology to improve plant efficiency by 1983.

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*Early leasing will not advance the time schedule due to the scheduling of needed technological improvements.

(b) Lassen and Glass Mountain.

Both of these resources are expected to benefit from the technology and demonstration efforts proposed for the Geysers hot water resources. In addition the following actions are required:

- Tax incentives in 1978.
- Support to the Forest Service to lease Glass Mountain by April 1980.
- Establish leasing priority and initiating environmental studies to lease Lassen by April 1980.

(5) Additional Prospects

There are numerous other potential prospects in the State in addition to the twelve discussed. These include the other KGRA's, numerous hot springs and areas under non-competitive lease application. These additional prospects are expected to add greatly to the states identified geothermal potential. All of the "additional prospects" are expected to benefit from the program actions already recommended. The key to encouraging exploration to "discover" these additional prospects include:

- Tax incentives in 1978.
- Expanded resource assessment activities in 1978-1980 to help establish leasing priorities.
- Establishing leasing schedule by 1980 and implementing the required leasing program.
- Proof that resource discovery can produce revenue (a successful demonstration plant).

SECTION I

INTRODUCTION AND BACKGROUND

Geothermal energy has the potential to satisfy a large part of California's growing need for electrical power in the post 1985 time period. This section includes discussions on: (1) the current knowledge of the state's geothermal resources, (2) the level of both exploration companies and utility companies needed commitments to realize the growth in geothermal utilization postulated and (3) an explanation of the conditions placed on such a commitment by industry and the potentially affected public.

A. THE POTENTIAL ROLE OF GEOTHERMAL ENERGY RESOURCES IN MEETING CALIFORNIA'S ELECTRICAL ENERGY NEEDS

1. Electrical Load Growth Forecast

The CERCDC has recently completed a report* (Reference 1) forecasting the electrical load growth through 1995 of the state's five major electrical utilities: the Los Angeles Department of Water and Power (LADWP), Pacific Gas and Electric Company (PG&E), Sacramento Municipal Utility District (SMUD), Southern California Edison Company (SCE) and San Diego Gas and Electric Company (SDG&E). The forecasts of the five major utilities include demands for various small resale customers and municipal utilities and represent 97.7 percent of the statewide sales. The remaining 2.3 percent are accounted for by the California Department of Water Resources (CDWR), Imperial Irrigation District (IID), Pacific Power and Light (PPL), California-Pacific Utilities Company (CPU), Sierra Pacific Power (SPP), and Surprise Valley Electrification Corporation (SVEC). The Commission analysis included both high and low conditional forecasts. The overall low growth rate of 1.8 percent forecast for the period of 1975-1995 was based on the assumptions of low economic growth, high electricity prices, high natural gas availability (and costs), conservation and post 1985 load management. The overall high growth rate forecast of 6.7 percent was based on high economic growth, low electricity and gas prices, and natural gas shortages. The Commission adopted growth rates of 4.0 percent (1975 to 1985) and 3.7 percent (1975-1995) as most likely. The Commission-adopted, peak-demand forecast is given in Table 1-1. The data show that the peak demand in the state will more than double between 1975 and 1995.

Geothermal power plants are most likely to be considered for base-load applications rather than for intermediate and peak-power requirements as it is desirable that the production of steam and hot water from geothermal wells be continuous. It is difficult to shut down the wells and restart production rapidly. The total new base load capacity will consist of:

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*The CERCDC has recently updated its forecast in its Biennial Report 1977, Vol. II.

Table 1-1. Commission Adopted Peak Demand Forecast (Megawatts)

Utility Service Area	1975	1980	1985	Growth Rate (75-85)	1990	1995	Growth Rate (75-95)
LADWP	4,099	4,944	5,677	3.3%	6,531	7,573	3.1%
PG&E	11,711	13,584	16,567	3.5	19,081	21,850	3.2
SMUD	1,272	1,546	1,823	3.7	2.069	2,350	3.1
SDG&E	1,619	2,234	3,006	6.4	3,971	4,985	5.8
SCE	10,193	12,901	15,864	4.5	18,581	23,288	4.2
TOTAL	28,894	35,209	42,937	4.0*	50,233	60,046	3.7*

*Most likely per CERCDC

(1) The power plant capacity additions required to meet the increasing demand.

(2) The capacity additions required to replace old plants retired or downgraded from base to intermediate load.

In 1975 the installed base load capacity in the state was 18,150 MW_e (Reference 2); 63% of the peak demand. Given that the 63% continues to be valid and the retirements and downgrades of 1975 base load capacity is as assumed then the new base load capacity additions required to 1995 are as shown in Table 1-2. Approximately 10,000 MW_e of new base-load capacity will be required by 1985 and an additional 14,000 MW_e in the 1985 to 1995 time period.

The electrical utilities are interested in establishing geothermal energy as a viable alternative to fossil fueled and nuclear power plants to meet the electrical demand. Natural gas is no longer available for use in power plant applications. Because of the expected escalation in oil prices (See Reference 2), forecasts indicate oil-fired plants will become economically non-competitive with coal and nuclear energy in the early 1980's. (The stringent California air pollution control requirements and the associated increased demand and competition for the limited supply of low-sulfur oil makes the oil price escalation process particularly acute for California.) For these reasons the utilities feel that the need to reduce their dependence on oil as a source of electric power is inevitable. Currently, coal-fired and nuclear power plants appear to be the only large established viable options for the 1980's and beyond. Both are economically attractive. However, the long lead times and the large environmental and regulatory uncertainties associated with their development make the planning and scheduling of capacity additions difficult. The cancellation of the Kapairowits coal-fired plant is a case in point. Both coal-fired and nuclear plants also

Table 1-2. New Base Load Capacity Additions (to 1975 Base)

	1975	1980	1985	1990	1995
Peak Demand (MW_e)	28,900	35,200	42,950	50,250	60,050
Base load capacity (MW_e)(1)	18,150	22,100	27,000	31,550	37,700
New base load capacity to meet increased load (MW_e)	N/A	3,950	8,850	13,400	19,550
Retirement and downgrades of 1975 base load capacity	N/A	---	1,000(2)	2,500(3)	4,000(2)
Total new base load capacity required (MW_e) over 1975 base	N/A	3,950	9,850	15,900	23,550

(1) Assumed 63% of peak demand
(2) Reference 2
(3) Assumed by author

require large, early capital commitments by the utilities. Geothermal power plants, on the other hand, are characterized by short lead times once the resource is proven, smaller unit size (i,e., 50 - 100 MW_e), smaller capital commitment (compared with the larger coal fired and nuclear plants), and higher (apparent) degree of environmental acceptability. All of these factors, coupled with encouraging economically competitive projections, make geothermal energy potentially an attractive option.

2. Geothermal Energy Development Scenarios

Power-on line scenarios have been made for each of 12 major geothermal prospects in the state (Section III). These prospects include:

(1) The Geysers steam field
(2) The Geysers hot water prospects
(3) Salton Sea KGRA
(4) Heber KGRA
(5) Brawley KGRA
(6) East Mesa KGRA
(7) Long Valley KGRA
(8) Coso Hot Springs KGRA
(9) Surprise Valley KGRA

(10) Glass Mountain KGRA
(11) Lassen KGRA
(12) Wendel-Amedee KGRA

An additional scenario was prepared to account for future discoveries which are expected to add new prospects and/or increase the estimated potential of the 12 identified prospects. Table 1-3 presents a summary of the near-term yearly power-on-line additions of these scenarios. Table 1-4 shows the cumulative total of each scenario by subregion. (A 30 year lifetime was assumed for each power plant which accounts for the drop in capacity in later years.)

Figure 1-1 shows the composite of the scenarios for each of the four subregions of the state as well as that for future discoveries which would be distributed among the four given subregion as well as the Central Coast subregion. The composite shows that in the near-term (i.e., through 1990) the major geothermal energy contributions to on-line capacity will come from the planned expansion of the existing Geysers steam field and from development of the four identified prospects in the Imperial Valley, (Heber, East Mesa, the Salton Sea and Brawley). Development in the Eastern Sierras and the Northeast, initiated in the mid 1980s, begins to contribute significantly in the 1990s. The exploration of the 1980's will result in new discoveries which will be very important in the rate of growth in geothermal utilization in the post 1990 time period.

In developing many of the scenarios various assumptions were necessary to define critical development program requirement, to permit expediting and prioritizing plans for necessary supportive actions and technological developments, as well as to provide reference for actual programs. Assumptions were made relative to:

(1) The earliest date that a power plant could be placed on-line considering such factors as the current state of development, marketability, local attitudes toward development, and the time (schedule) required to complete power plant development.

(2) The estimated electrical potential of each prospect.

(3) The rate at which expansion of each prospect may proceed considering resource magnitude and quality, marketability and again local attitudes toward development.

In the case of the Geysers steam field there are currently 502 MW_e on line and industry plans to expand the development to the full field potential. On the four prospects in the Imperial Valley, resource assessment and confirmation is reasonably well advanced. The assumptions on first plant-on-line for the various scenarios are based on realizable plans to significantly contribute to California's energy needs. The remaining scenarios depend more upon assumptions. Each of the scenarios is discussed in more detail in Section III.

Table 1-3. California Near Term Scenarios (Power On-Line MW_e)

Prospects	TO 1978	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
	Calendar Year													
Geysers "Steam"	502	161	245	-	220	220	220	200	110	110				
Reservoirs Under Production Verification														
Salton Sea			10(P)			50		50	50	50	100	100	100	100
Heber					50(D)			50		50	50	100	100	100
Brawley							50		50	50	50	100	100	100
East Mesa		10(P)				50			50		50	50	50	50
Reservoirs Under Exploratory Drilling														
Geysers "Hot Water"							50		100	100	100	100	100	100
Long Valley									50			100		100
Coso									50	50	100	100	150	150
Surprise Valley							50			50		50	50	100
Potentially High Heat Content														
Glass Mtn											50		50	100
Lassen											50		50	100
Wendel-Amedee												50		
Additional Prospects										50	100	150	200	250
On-Line MW_e Per Year	502	171	255	-	270	320	370	320	460	510	650	850	950	1250
Cumulative MW_e (To Nearest 100 MW_e)	500	700	900	900	1200	1500	1900	2200	2700	3200	3800	4700	5600	7000

Table 1-4. California Scenario Cumulative by Subregion - MW_e (Assumed 30 yr Lifetime)

Subregion	Assumed Potential MW_e	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
Geysers:											
Steam	2000	502	908	1898	2000	2000	2000	1500	1100	-	-
Hot Water	2000	-	-	150	650	1150	1650	2000	2000	1850	1350
Subtotal	4000	502	908	2048	2650	3150	3650	3500	3100	1850	1350
Imperial:											
Salton Sea	2000	-	10	160	610	1100	1610	2000	1990	1840	1390
Brawley	1000	-	-	100	500	1000	1000	1000	1000	900	500
Heber	1000	-	-	100	500	1000	1000	1000	1000	900	500
East Mesa	500	-	10	100	300	500	500	500	490	400	200
Subtotal	4500	-	20	460	1910	3600	4110	4500	4480	4040	2590
Eastern Sierra:											
Long Valley-Mono	2000	-	-	50	250	750	1250	1750	2000	1950	1750
Coso	2000	-	-	50	600	1350	2000	2000	2000	1950	1400
Subtotal	4000	-	-	100	850	2100	3250	3750	4000	3900	3150
Northeast:											
Surprise Valley	2000	-	-	50	250	750	1250	1750	2000	1950	1750
Glass Mountain	1000	-	-	-	200	700	1000	1000	1000	1000	800
Lassen	1000	-	-	-	200	700	1000	1000	1000	1000	800
Wendel Amedee	500	-	-	-	50	300	500	500	500	500	450
Subtotal	4500	-	-	50	700	2450	3750	4250	4500	4450	3800
Additional Prospects	13,000				750	2600	4600	6600	8600	10,600	11,150
Total	30,000	502	928	2658	6860	13,900	19,360	22,600	24,680	24,840	22,040

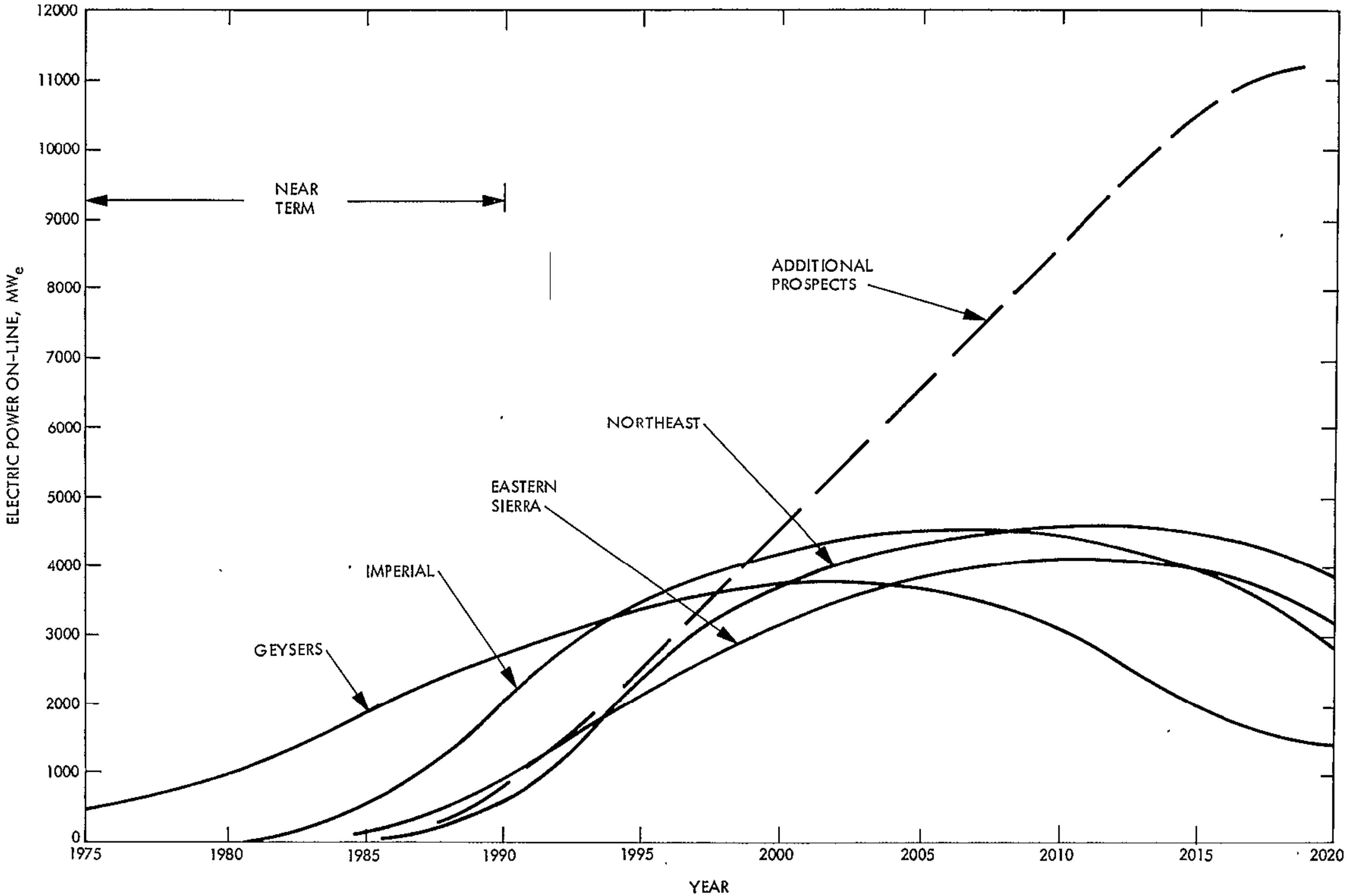

Figure 1-1. Subregion Scenarios (Hydrothermal Resources)

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3. The Significance of the Geothermal Energy Option

The significance of realizing all or a major portion of the geothermal growth postulated in the scenarios is illustrated in Figure 1-2 which compares the base load additions from Table 1-2 with the composite California geothermal growth scenario summarized in Table 1-4. On the basis of the scenario-data geothermal energy has the potential of meeting all the state's base load addition requirements in the post 1990 time period and a major fraction of additions during the 1985-1990 time period. The realization of the scenarios and the establishment of the viable geothermal option in the state require the commitments and actions discussed in detail in the following section:

(1) Full development of the steam field of the Geysers by 1985.

(2) Commercial power plant development on the identified hot-water resources in the Imperial Valley in the early 1980's.

(3) Increased resource exploration, and leasing activities, in the remainder of the 1970's and 1980's to discover and prove those geothermal resources in the Eastern Sierra, Northeast and extended Geysers areas necessary for the significant growth of the post 1985 time period.

These commitments will not be met until there is mutual confidence on the part of industry, the affected public, and the regulatory agencies that the geothermal energy option offers significant advantages over the existing energy alternatives.

The viability of the geothermal energy option depends on establishing mutual confidence in the following:

(1) That there is a large, commercially exploitable geothermal resource.

(2) That the use of geothermal energy is technically and economically competitive with alternative sources of energy.

(3) That the development and utilization of geothermal energy can and will be environmentally acceptable and compatible with local community desire.

(4) That the development and utilization of geothermal energy resources can procede without lengthy regulatory delays.

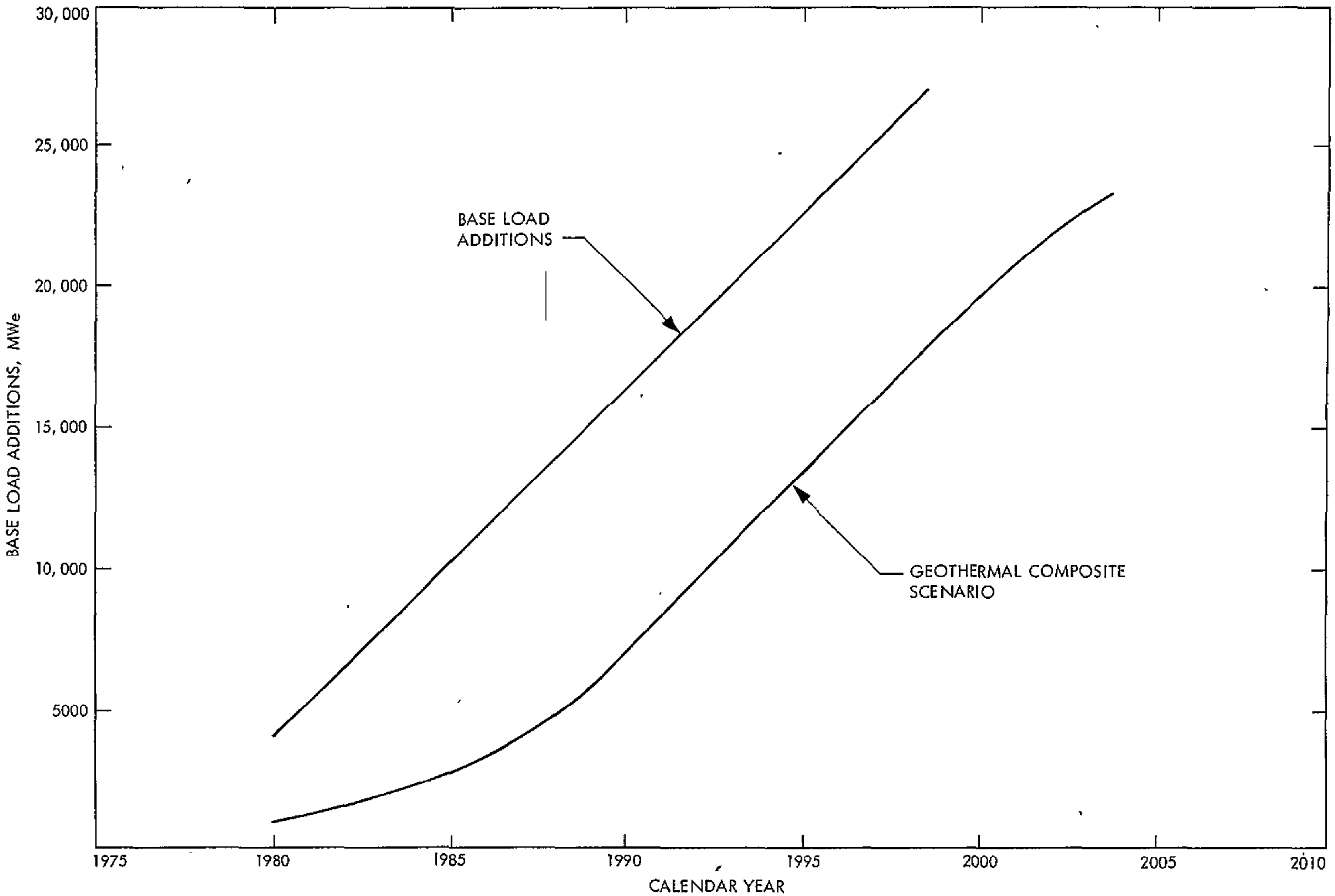


Figure 1-2. Potential Contribution of Geothermal Energy to California's New Base Load Additions

B. ACCELERATING GEOTHERMAL ENERGY DEVELOPMENT

1. Resource Knowledge and Scenario Assumptions

California is particularly rich in geothermal resources. They include not only the more familiar hydrothermal systems typified by those under development at The Geysers in Northern California and in the Imperial Valley but also hot-igneous (i.e., magma and hot dry rock) and conduction dominated (i.e., near-normal-temperature gradient) systems which may ultimately prove to be much more extensive and valuable than the hydrothermal systems. A summary of the heat content of California's geothermal resources based on United State Geological Survey (USGS) estimates is given in Table 1-5. The high temperature hydrothermal system (i.e., those having temperatures over 150°C) are especially important because of their potential for near term commercial development for electrical power generation and are the subject of this report.

Table 1-5. Heat Content of California's Geothermal Resource Base (Heat in Ground Above 15°C Without Regard to Recoverability)*

Resource Type	Energy Content in Quads**	
	Identified	Undiscovered
Hydrothermal		
Vapor-Dominated (Steam)	75	75
Liquid-Dominated (Hot Water)		
o High Temperature (>150°C)	650	2000
o Intermediate Temperature (90-150°C)	30	120
Hot-Igneous	14,700	55,000
Conduction-Dominated		
o Near Normal Gradient	>635,000	0
o Geopressured	Unknown	Unknown

*Reference 3

**1 Quad = 10^{15} BTU's and is equivalent to approximately 170 million barrels of oil or 50 million short tons of coal

The identified hydrothermal resources in California are located in and around "Known Geothermal Resource Areas" (KGRAs). A KGRA, as defined in the rules and regulations implementing the Geothermal Steam Act of 1970 (PL 91-581), "is an area in which the geology, near by discoveries, competitive interests, or other indicia would, in the opinion of the Secretary of the Interior, engender a belief in men who are experienced in the subject matter that the prospects for extraction of geothermal steam or associated resources are good enough to warrant expenditures or money for that purpose." There are 23 such designated areas in the state (Figure 1-3). The USGS has the responsibility of assessing the nation's geothermal potential. Their initial assessment was released in 1975 (Reference 4). It identifies 62 hydrothermal resources in California with estimated temperatures greater than 90°C; 46 below 150°C and 16 greater than 150°C. Those resources above 150°C are of commercial interest for the generation of electrical power. Twenty-eight of the 62 identified resources are associated with one of the state's KGRA's as is shown in Table 1-6. Of the 23 KRGA's, only 5 have no identified hydrothermal systems. Here "identified" is used in the context of having been included in the USGS assessment. (It should not be inferred that no resource exists if not listed in the USGs assessment.) These five include Bodie, Beckwourth Peak, Ford Dry Lake, Glass Mountain and Saline Valley KGRA's. On the basis of its volcanic nature and the large number of lease applications, Glass Mountain KGRA appears to be a very promising geothermal area, but has yet to be completely assessed. There are thermal springs located near the Saline Valley KGRA. Bodie, Beckwourth Peak and Ford Dry Lake were established as KGRA's on the basis of overlapping geothermal lease applications. Based on the available USGS data, then, the identified electrical potential in the state in excess of 19,000 MW_e distributed in 9 KGRA's. These are listed in Table 1-7.

There are large uncertainties in the resource estimates. It is important to recognize that the USGS assessment was based on the limited data available at the time the survey was performed (prior to 1975). As the USGS has indicated (Reference 5), no single estimate of geothermal energy from a particular area included in the assessment should be relied upon as an established fact. For some areas the information was relatively good; for others it was very poor at the time the estimate was made. To illustrate the paucity of data, of the 46 identified resources with the temperatures between 90° and 150°C, 37 have limited extent data (i.e., subsurface areas and thickness) as do 8 of the 16 identified systems above 150°C. During the past two years, more data on the resource has become available. The USGS plans to update its assessment in 1978.

While the estimated geothermal potential of the state is large, only a small fraction of that potential has been confirmed by deep drilling and reservoir confirmation tests. Table 1-8 summarizes the geothermal wells which have been drilled in the state by KGRA and subregion (References 6 and 7). Two thirds of the wells drilled are associated with the development of The Geysers steam field. In the past few years, there has been limited exploratory drilling outside of The Geysers and Imperial Valley, due in a large part to limited leasing of promising federal lands. With the exceptions of the Geysers, Heber, Brawley, East Mesa, Salton Sea,

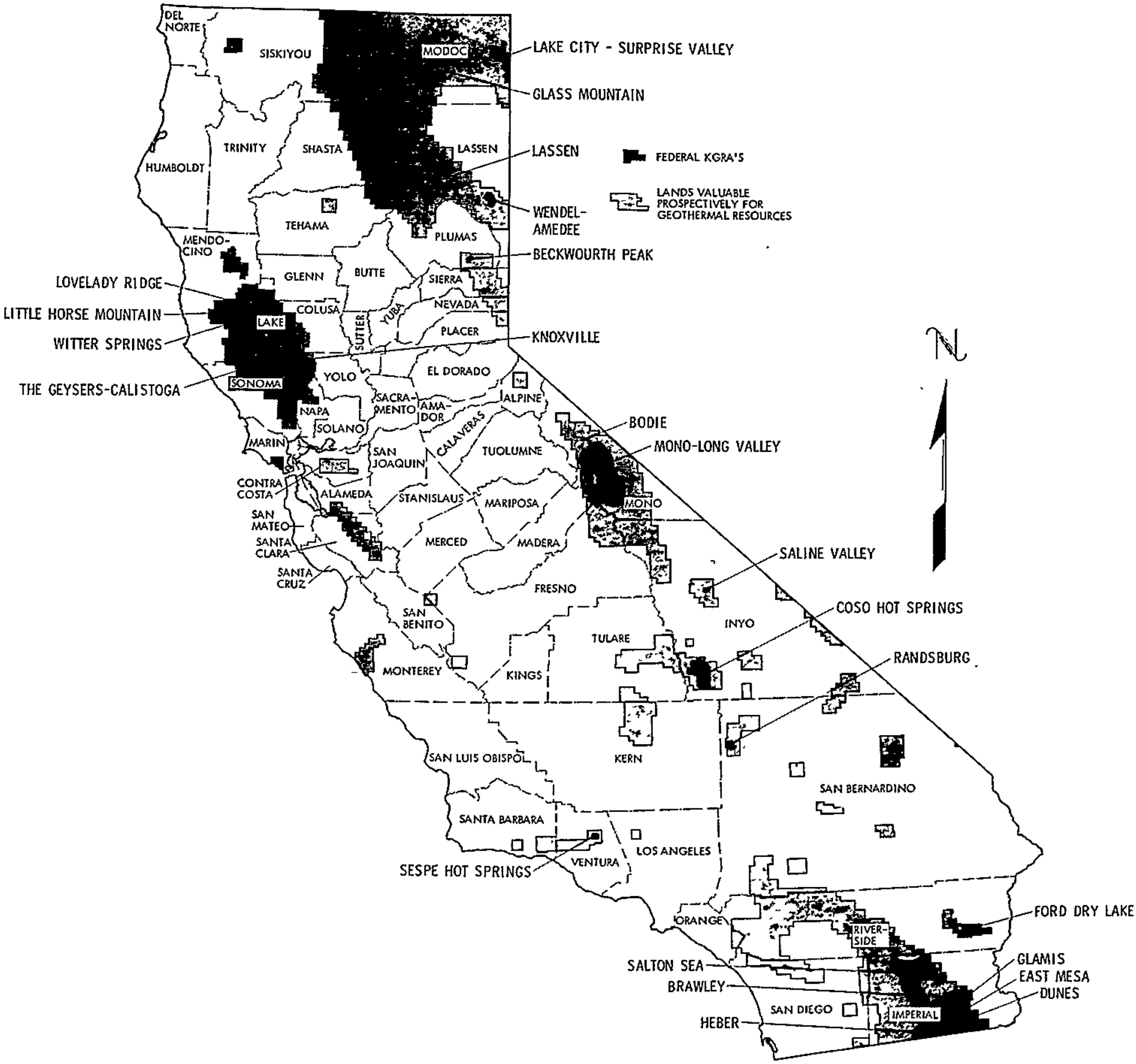


Figure 1-3. California's Known Geothermal Resource Areas

Table 1-6. Identified Potential of Known Geothermal Resource Areas

Location/KGRA	Circular 726 Designation	Estimated Reservoir Temperature, °C	Total Reservoir Heat Content, quads	Electric Energy Potential MW_e for 30 years
		THE GEYSERS REGION		
Geysers-Calistoga	The Geysers	240	75	1589
	Calistoga	160	3	70
	Sulphur Bank Mine	185	≈ 2	37
	Skagg's Hot Spg. (a)	155	1	27
	Wilbur Hot Spg. (a)	135	10	(c)
Knoxville	One Shot Mining	150	≈ 1	(c)
Little Horse Mtn.	Crabtree Hot Spg.	150	≈ 1	(c)
Lovelady Ridge	Cook Springs	140	≈ 1	(c)
Witter Springs	Saratoga Springs	140	≈ 1	(c)
			95	1722
		IMPERIAL VALLEY REGION		
Brawley	Brawley	200	12	333
Dunes	Dunes	135	≈ 2	(c)
East Mesa	East Mesa	180	22	487
	Border	160	≈ 1	(c)
Ford Dry Lake	(b)	-	≈	-
Glamis	Glamis (East)	135	≈ 2	(c)
Heber	Heber	190	44	973
Salton Sea	Salton Sea	340	83	2786
	Pilger Estate H. S.	145	≈ 1	(c)
			167	4579
		EASTERN SIERRA REGION		
Bodie	(b)	-	-	-
Coso Hot Springs	Coso Hot Spg.	220	163	4533
Mono Long Valley	Long Valley	220	218	6083
	Near Black Pt.	125	≈ 1	(c)
	Paoha Island	125	≈ 1	(c)
	Red's Meadow	165	≈ 1	
Randsburg	Randsburg	125	≈ 2	(c)
Saline Valley	(b)	-	-	-
			386	10,616
		NORTHEAST REGION		
Beckwourth Peak	(b)	-	-	-
Glass Mountain	(b)	-	-	-
Lake City-Surprise Valley	Surprise Valley	175	95	2123
Lassen (d)	Morgan Springs	210	≈ 5	133
Wendel-Amedee	Wendel-Amedee	140	≈ 5	(c)
			130	2256
		CENTRAL COAST REGION		
Sespe Hot Springs	Sespe Hot Spg.	155	≈ 1	(c)

Notes:

(a) Outside of KGRA boundaries.
(b) No identified system.
(c) No estimate due to limited knowledge or insufficient temperature.
(d) Excludes Lassen National Park.

Table 1-7. California KGRAs with Identified* Electrical Energy Potential

KGRA	Electrical Energy Potential (MW_e for 30 years)
1. Mono-Long Valley	6100
2. Coso Hot Springs	4500
3. Salton Sea	2800
4. Lake City-Surprise Valley	2100
5. Geysers-Calistoga	1750
6. Heber	970
7. East Mesa	500
8. Brawley	330
9. Lassen	150
	19,200

*Included in the USGS assessment of 1975

Surprise Valley and Long Valley KGRAs, the existence and extent of geothermal reservoirs has yet to be confirmed by deep drilling. On the basis of the number of wells and reservoir assessment activities, it is estimated that on the order of 2100 MW_e have been proven; 1200 MW_e in The Geyers, 600 MW_e in the Imperial Valley and less than 100 MW_e in Long Valley and Surprise Valley as is indicated in Table 1-9. Additional resources can be inferred from the extrapolation of geologic and well data. It is the proven resource on which utility commitment is based.

There are understandably considerable differences in expert opinion on the potential of the various resources. As a result it was necessary to make assumptions for the scenarios relative to potential magnitude for various identified prospects in the state. These estimates, presented in Table 1-10, are based on the USGS data modified in meetings with the industry panel and with DOE. In general, the industry panel felt comfortable with a 4,000 - 5,000 MW_e capacity limit for the Geysers Subregion and 6,000 MW_e for the Imperial Valley; 4,000 and 4,500 MW_e respectively were assumed for this report. Industry felt that the USGS estimate of 10,000 MW_e potential for Coso and Long Valley was extremely optimistic based on the relative lack of success in deep drilling; 4,000 was assumed. Industry made no estimate for the Northeast or Central Coast subregions, however, they did comment that the Northeast subregion was very promising geologically. This report assumes 4,500 and 1,000 MW_e potential for the Northeast and Central Coast subregions, respectively.

Table 1-8. Geothermal Wells in California*

KGRA	Wells Pre-1971	1971	1972	1973	1974	1975	1976	Total Wells
Geysers:								
• Geyser-Calistoga								
• Main Field	98	12	15	21	21	24	22	213
• Other	3	1	3	0	0	1	8	16
• Knoxville	0	0	0	0	0	0	0	0
• Little Horse Mountain	0	0	0	0	0	0	0	0
• Lovelady Ridge	0	0	0	0	0	0	0	0
• Witter Springs	0	0	0	0	0	0	0	0
• Other	2	0	0	0	0	0	0	2
Subtotal	103	13	18	21	21	25	30	231
Imperial:								
• Brawley	1	0	0	0	0	3	2	6
• Dunes	0	0	1	0	0	0	0	1
• East Mesa	0	0	2	2	3	2	3	12(2)
• Glamis	0	0	0	0	0	0	0	0
• Heber	0	0	3	1	3	4	5	16
• Salton Sea	15	0	6	0	1	0	6(1)	28
• Ford Dry Lake	0	0	0	0	0	0	0	0
• Other	0	0	0	3	0	0	0	3
Subtotal	16	0	12	6	7	9	16	66
Eastern Sierra:								
• Bodie	0	0	0	0	0	0	0	0
• Coso	0	0	0	0	0	0	1	1
• Mono Long Valley	10	2	0	0	0	0	1	13
• Randsburg	1	0	0	0	0	0	0	1
• Saline Valley	0	0	0	0	0	0	0	0
• Other	2	0	0	0	0	0	0	2
Subtotal	13	2	0	0	0	0	2	17
Northeast:								
• Beckwourth	0	0	0	1	0	0	0	1
• Glass Mtn	0	0	0	0	0	0	0	0
• Lake City-Surprise Valley	5	0	1	2	1	0	0	9
• Lassen	1	0	0	0	0	0	0	1
• Wendel-Amedee	4	0	0	2	0	0	0	6
• Other	1	0	0	0	0	1	0	2
Subtotal	11	0	1	5	1	1	0	19
Central Coast:								
• Sespe	0	0	0	0	0	0	0	0
Total	143	15	31	32	29	35	48	333

(1) Republic Geothermal Wells at Westmoreland.
(2) Includes 5 Bur wells.

*See References 6 and 7.

Table 1-9. Estimated Proven Resource Potential

KGRA	USGS Assessment Data MW_e	Proven* Resource MWe
Geyers Calistoga	1750	1200
Brawley	330	200
East Mesa	500	100
Salton Sea	2800	200
Heber	970	300
Mono-Long Valley	6100	50
Surprise Valley	2100	50
Coso	4500	0
Lassen	150	0
	19200	2100

*Considerably more resource potential can be inferred from the "proven" wells and geologic data

It is expected that further exploration will show a significant number of additional geothermal fields in the state with electric energy potential besides those listed. Further exploration also could considerably modify the estimates for the sites identified. Future discoveries, according to the USGS, could be possibly five times the volume and heat content of the high temperature systems (>150°C) already identified. These discoveries could result from:

(1) New knowledge of the extent of an already identified system that appreciably increases its estimated volume.

(2) The temperature of an identified system being higher than first estimated (enough possibly to raise some of the 46 moderate temperature resources into the higher temperature category).

(3) The discovery of a previously unknown system.

This report assumes these new discoveries could add another 13,000 MW_e to the resource base.

Table 1-10. Summary of Resource Potential Estimates (MW_e for 30 yr)

Resource	Assumed Temp °C	USGS No. 726 5/75	Industry Panel 5/76	ERDA 2/77	Scenario Assumption
Geysers:					
Steam	240	1600	2000	2000	2000
Hot Water	200	≈150	2-3000	1000	2000
Imperial:					
Salton Sea	300	2800	2500	2000	2000
Brawley	300	330	>1000	1000	1000
Heber	190	970	>1000	1000	1000
East Mesa	180	500	>500 (2)	400	500
Eastern Sierra:					
Mono-Long Valley	220	6100	(3)	2000	2000
Coso	220	4500		2000	2000
Northeast:					
Surprise Valley	175	2100		2000	2000
Lassen	220	≈150	(4)	1000	1000
Glass Mountain	200	-		1000	1000
Wendel-Amedee	175	-		-	500
Central Coast:					
Sespe	-	-	-	-	-
Diablo Range	200	-	-	2000	1000
Additional Prospects					
Steam		X2	-	-	1000
Hot Water		X5 (1)	-	-	11,000
Totals		19,200(5)	-	17,400(5)	30,000

Notes:

(1) USGS factors for total U.S.
(2) Felt total near 6000.
(3) Felt USGS Est too high.
(4) Felt subregion to be very promising.
(5) Excluding additional prospects.

2. Scenario Commitment Requirements

Figure 1-4 is the near-term power-on-line composite scenario showing the potential contributions of The Geysers steam field and the hot water resources. Through the mid 1980's the main contribution will be from the planned expansion of The Geysers steam field to a level of 2000 MW_e. The post 1985 growth will have to be based on the utilization of the more abundant hot-water resources. Also shown in Figure 1-4 is a simplified time-line for geothermal development. It takes on the order of 8.5 to 9.5 years to complete the development cycle for the first power plant for a given resource.

Because of the long lead time associated with resource exploration and power plant development, the post 1985 growth in the utilization of the hot-water resources is dependent on the exploration company and utility actions of the late 1970's and early 1980's. Figure 1-5 shows the level of commitment required to support the scenario. (See Appendix B) The number of deep exploration and resource characterization wells per year to establish the proven reserves must increase from 20 wells per year in 1977 to over 200 per year in 1985. The cost of these wells can range from $300,000 to over $1,000,000 per well dependent on depth and rock structure (i.e., sedimentary or volcanic). This level of drilling activity represents a sizeable investment by the exploration companies. The commitment by utilities to new geothermal plant capacity, as determined by the filing of Notices of Intention, must increase from 250 MW_e per year in 1977 to 1400 MW by 1988. Because of the assumed limit of the Geysers steam field the scenarios indicate that after 1983 commitments to new power plants will be based totally on its hot-water resources.

3. Current Development Outlook

The viability of the steam resources is well established; 502 MW_e are on-line at The Geysers with utility plans to expand development to an estimated 2000 MW_e capacity in the 1985 time frame. Currently, development is paced by the resolution of the H_2S emission air quality problem and the resolution of land use issues. Both are receiving concentrated attention.

On the other hand, the viability of the hot-water resources, is not established. Little of the hot-water resource potential outside of the Imperial Valley has been proven by deep drilling. Studies (See Reference 2) show that the cost of power from the identified hot-water resources are not now competitive with alternative sources of energy. In addition, there are large uncertainties in cost and in understanding of performance characteristics which need to be resolved. As a result, there is only limited commitment to the hot-water resources at this time.

Currently, there are active research and development projects in the Imperial Valley to demonstrate the technology and to reduce cost and performance uncertainties. These include both test facilities and pilot plants. In addition, a commercial-scale, 50 MW_e demonstration

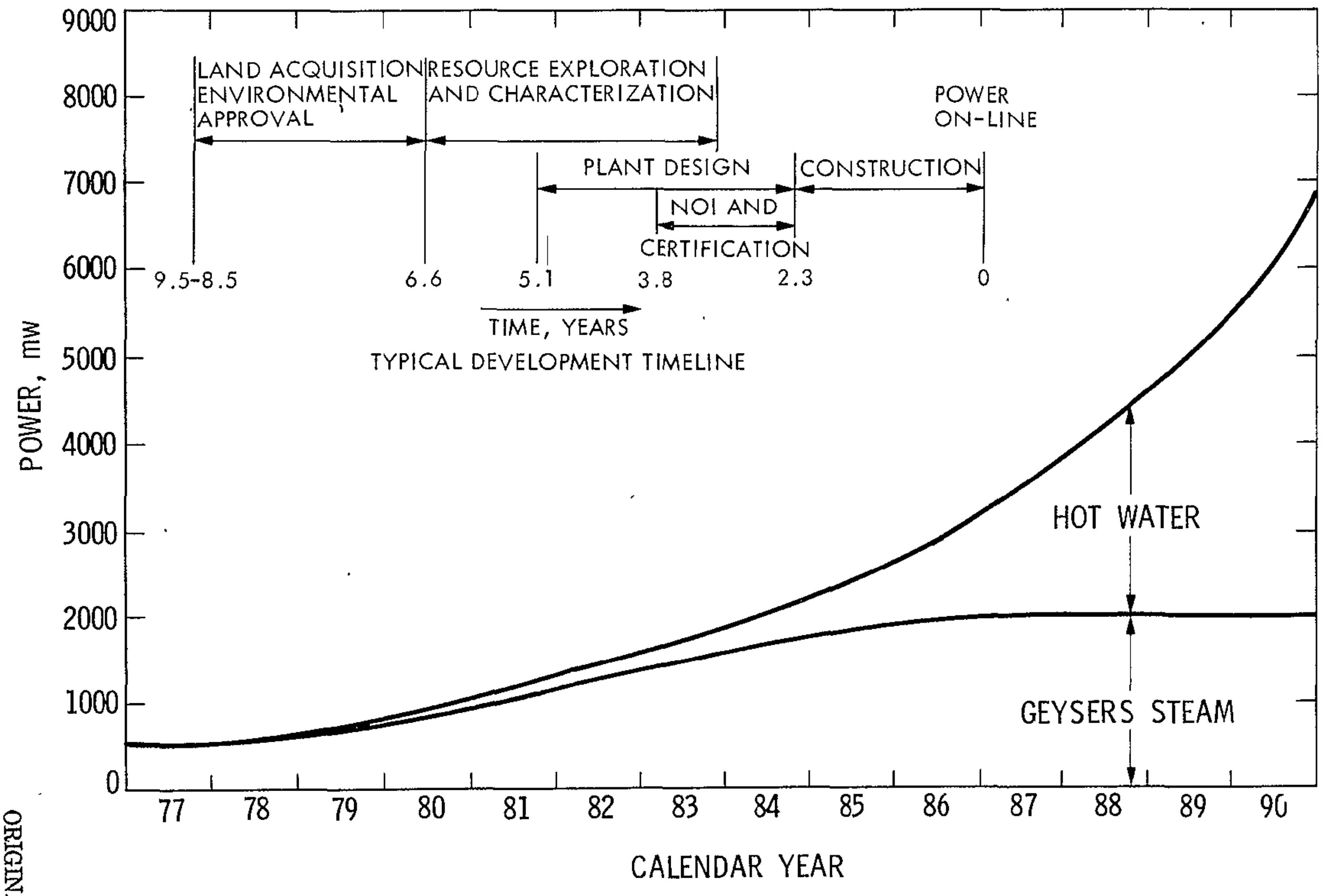
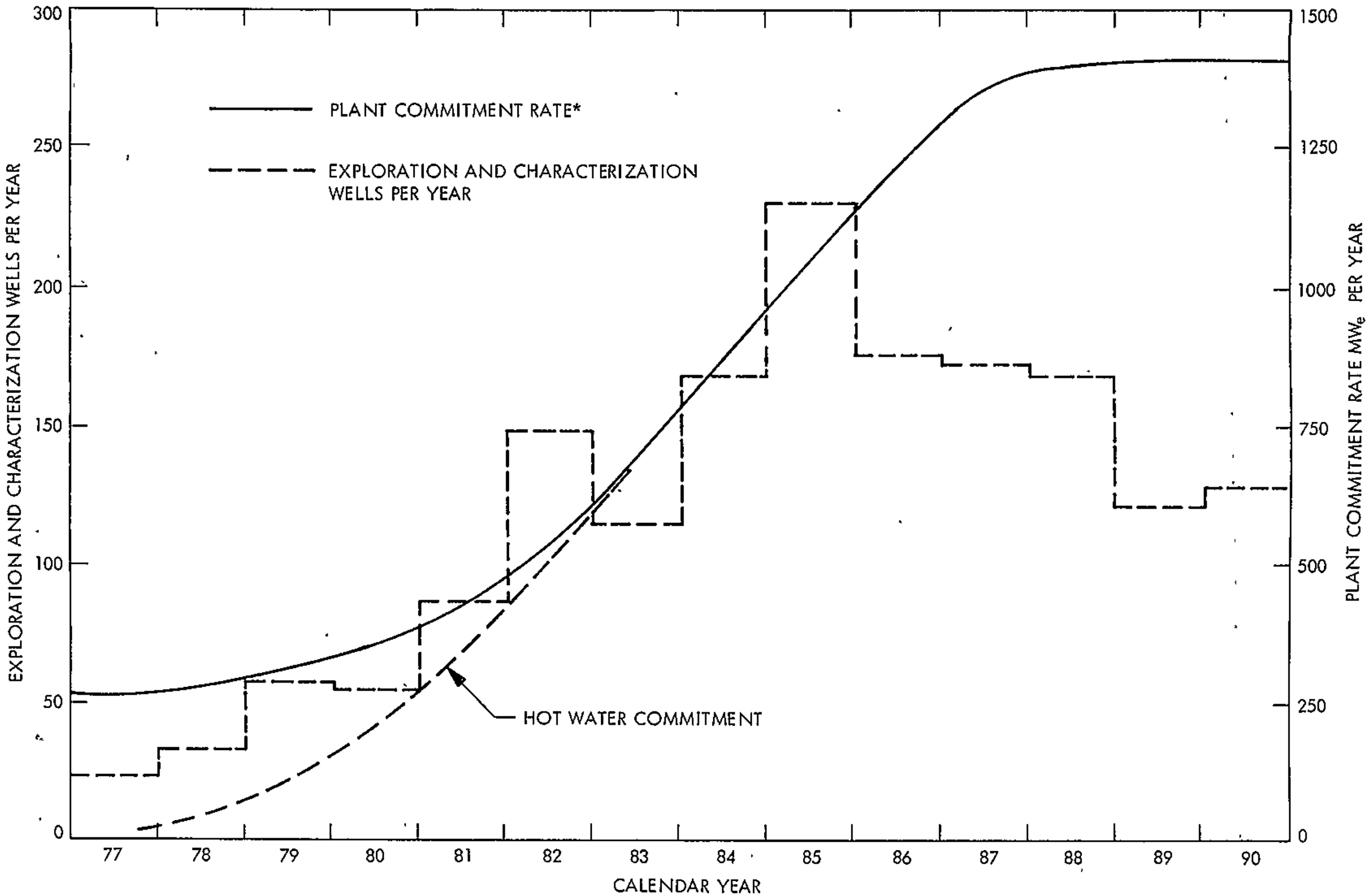


Figure 1-4. Near Term Power On-Line Development Scenario



*COMMITMENT BASED ON UTILITY FILING OF NOTICE OF INTENT.

Figure 1-5. Scenario Exploration and Plant Commitment Rate Requirements

plant is under consideration. While these projects will contribute significantly to increasing user confidence, they in themselves will not be sufficient either to establish the viability of power generation from hot-water resources or to assure the necessary commitments to achieve the growth postulated in the scenario. Additional actions discussed later in this report will be required.

4. Conditions on Commitment

The commitment of three primary groups is necessary to assure a rapid increase geothermal electrical utilization growth; the exploration companies the utilities and the public (and the regulatory agencies representing the public).

Because of the large associated costs, there is little incentive for exploration companies to pursue vigorous deep drilling programs without some assurance that the resource will be used in a timely fashion. There is only limited utility commitment to the use of geothermal energy outside of the economically attractive Geysers steam field. Therefore, one of the keys to increasing the exploration rate for the hot-water resources is increased commitment by the utilities. Utilities do recognize that the hot-water resources are potentially attractive sources of electrical power. Many are actively considering the geothermal energy option in their growth plans. However, because of the high projected costs and uncertainties, they are reluctant to commit at this time. The use of geothermal energy is a new technology to most utilities and as a result, it poses significant economic, environmental, technical, and socio-political concerns and uncertainties as compared with established energy options. This is particularly the case with the hot-water resources and to some degree even with The Geysers steam field. The utilities do acknowledge the number of excellent supportive technology development programs and studies on the utilization of geothermal resources and that the results to date are very encouraging. However, such studies and technology development programs are not sufficient for utility commitment; the technical unknowns and economic and environmental uncertainties associated with geothermal energy currently are just too large at this time. The four major concerns are:

(1) Reliability of operation.

(2) Assurance of reservoir capacity and lifetime.

(3) Economics of a geothermal plant compared with alternatives.

(4) Confidence in development schedules (i.e., freedom from lengthy environmental and regulatory delays).

As a result, utility personnel concerned with geothermal energy generally feel that, outside of The Geysers steam field, geothermal energy will not be considered as a viable alternative to fossil-fueled and nuclear plants by a utility company's board of directors until its reliability and economics are proven by a full scale demonstration plant. Such

a plant would help place the utilization of geothermal energy on an equivalent confidence base to those of oil, nuclear and coal.

Subsequent demonstration plants may be necessary for any facility involving significant new technology. In addition, the utilities generally will require that reservoir capacity and lifetime for each geothermal power plant be demonstrated by deep drilling and confirmation tests prior to their commitment.

The third group which must also commit to geothermal developments is the affected public and the associated regulatory agencies. Many localities and regulatory agencies have limited experience with geothermal energy. As a result they are understandably reluctant to approve geothermal developments without knowing the potential impact. The universal desire on the part of those agencies and the local communities is that all geothermal development proceed in an orderly, controlled manner consistent with local desires; minimizing any potential adverse impact. Both the California Environmental Quality Act (CEQA) and the National Environmental Protection Act (NEPA) assure that such concerns are addressed and resolved in the regulatory/approval process.

SECTION II

COMMON CALIFORNIA REGIONAL DEVELOPMENT REQUIREMENTS

There are issues common to most of the sub-regions or prospects within California which require solution if the power-development postulated by the scenarios is to be achieved. These common regional requirements are related to the state-wide, hot-water resources. Sub-region specific items, like development of The Geysers steam field, are discussed in Section III of this report.

This section discusses the four major issues common to California and makes recommendations for their resolution. They are:

(1) On the basis of current policies and technology, the cost of power from the hot-water resources is not now competitive with other sources of power.

(2) There are large cost and performance uncertainties associated with generating power from the available hot-water resources.

(3) The existing environmental review and permitting process is lengthy, unpredictable and frustrates development.

(4) The processing of federal leases has been slow. While leasing probably has not been a major factor limiting geothermal development in the Imperial Valley and the Geysers, it does pace development in the remainder of the state. This is particularly important in the critical KGRAs, of Mono-Long-Valley and COSO.

A. REDUCING THE COST OF GEOTHERMAL POWER

The achievement of any growth scenario for geothermal energy utilization will be predicated on the fundamental assumption that the cost of power produced from geothermal resources will be competitive with the cost of power produced from coal-fired or nuclear plants. There is strong industrial commitment to the development of The Geysers steam field where the demonstrated cost of power is lower than nuclear, coal or oil. On the other hand, there is only limited utility commitment to the use of the hot-water resource where the projected costs are higher than the alternatives.* Comparative cost data are given in Table 2-1. While there is no unanimity of opinion among the various investigators who have estimated the probable cost of electric power from hot-water resources, the range of estimated power cost runs from 10% to 150% more than the cost from other energy alternatives on the basis of current policies and

*CERCDC analyses indicate that there are uncertainties in both the current costs of nuclear and coal and in their escalation rates.

Table 2-1. Comparison of Costs For Future Generating Facilities (Constant 1976 Dollars)*

Type	Estimated Total Capital Investment ($\$/kW_e$)	Estimated Price of Electricity at Busbar (Mills/kWh)
Nuclear Power Plant (LWR)	720-830	29
Conventional Oil-Fired Power Plant (Low-Sulfur Oil)	350-400	34
Combined Cycle (Oil-Fired) Power Plant (Low-Sulfur Oil)	275-350	32
Coal-Fired Power Plant	570-600	29
Hydrothermal Power Plant		
Steam	250-280	20
Hot Water	520-800	47

*Taken from REFERENCE 2

technology. There are, of course, large uncertainties in these estimates; no hard data exists on power plant costs for hot water systems, or on field development costs. Further, the requirements of specific sites can introduce major differences in projected power costs from resources of similar characteristics. This section will look at the generic problems involved with bringing the cost of power from hot-water resources into the competitive range. Section III will deal with the problems related to specific sites.

1. Current Costs of Geothermal Power

The cost of geothermally derived power consists of two major components: (1) the power plant construction and operation cost, and (2) the fuel cost. The portion of the busbar cost of power ascribable to power plant construction and operations cost depends on the actual cost of construction, the fraction of this cost that is borrowed and the interest rate on the loan, the fraction that is invested from the utility's capital and the rate of return on that investment allowed by the regulatory agency, the period of amortization of the plant, the anticipated plant availability factor (i.e., the fraction of time the plant will be on-line), and the anticipated cost of operations. Each of these factors will

vary for a given project. Currently, there are no hot-water geothermal power plants in the United States on which to base either costs or plant availability.* Estimates of the cost of construction of geothermal hot-water plants have varied widely, from as low as $150/kW_e$ to as high as $750/kW_e$ (Reference 8). SRI, in its economic analysis, assumed a figure of $650/kW_e$, which at a 15% rate of return, a 0.80 plant availability factor, and a 30-year plant lifetime, translates into a busbar power cost ascribable to power plant costs of 18.7 mills/kW-h. For this analysis, JPL will assume a probable range of 16 mills/kW-h to 24 mils/kWh for this portion of the cost of power.

The other part of the cost of power is ascribable to fuel costs, i.e., what the developer charges the utility for the geothermal fluids. This depends on an even larger and more uncertain set of factors: the per-foot cost of drilling, the depth and quality of the resource, the cycle efficiency of the power plant, the tax treatment of costs and revenues, the time between investment and start of return, the required rate of return, the anticipated life of a well, and the anticipated power plant availability factor. The resultant wide spread in busbar cost of electricity ascribable to fuel cost is shown in Figures 2-1 through 2-3, where busbar fuel cost is plotted versus flowrate for a variety of well-head brine temperatures, for drilling costs of $400K, $600K, and $800K per well.** These data illustrate the variability of potential resource cost and also the importance of achieving low well costs and high flow rates for the lower temperature resources.*** For the assumptions used (a rate of return of 20%, plant availability factor of 0.75, and current tax policy), costs range from a low of about 15 mills/kWh for an exceptionally good well (275°C, 700K lbs/h, 11.6 MW_e) in an area easy to drill ($400K/well) to about 30 mills/kWh for what might be considered an average well (200°C, 500K lbs/h, 3.9 MW_e) in a moderately difficult drilling region ($600K/well), to over 70 mills/kWh for a poor well (175°C, 300K lbs/h, 1.7 MW_e) in a difficult drilling region ($800K/well).

To quantify the problem somewhat more, JPL has made a rough estimate of the cost-of-power range that might be expected for the various scenario prospects in the State, using relatively optimistic assumptions on flow-rate and temperature. Because the resources in many of these areas

*Foreign plants such as those in Mexico and New Zealand will be an aid to some technology development but will not yield usable costing data.

**These data are based on Figures 13 through 18 of Reference 2 modified for a given well-head temperature, a power plant utilization factor of 0.5 (representative of today's technology) and rejection temperature of 45°C.

***Dr. Robert Rex, President of Republic GeoChemical, Inc., has indicated that the lower temperature resources may characteristically have higher flow rates and be found at shallower depths than the higher temperature resources.

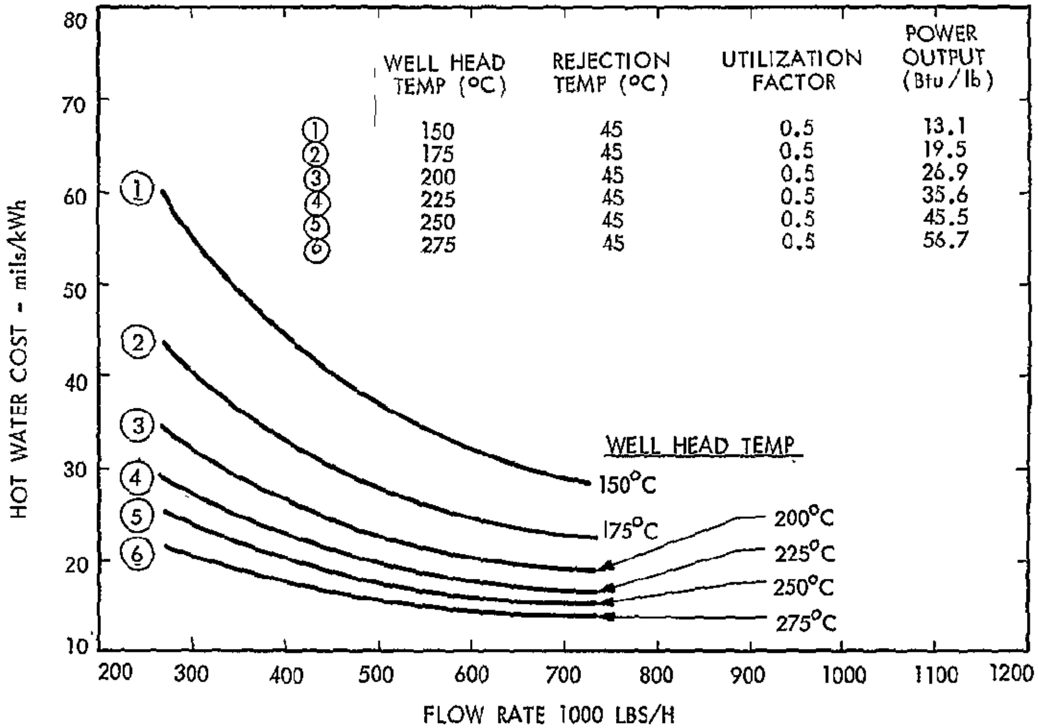


Figure 2-1. Resource Price Assuming Well Cost of $400,000 Per Well 75% Capacity, 20% Return

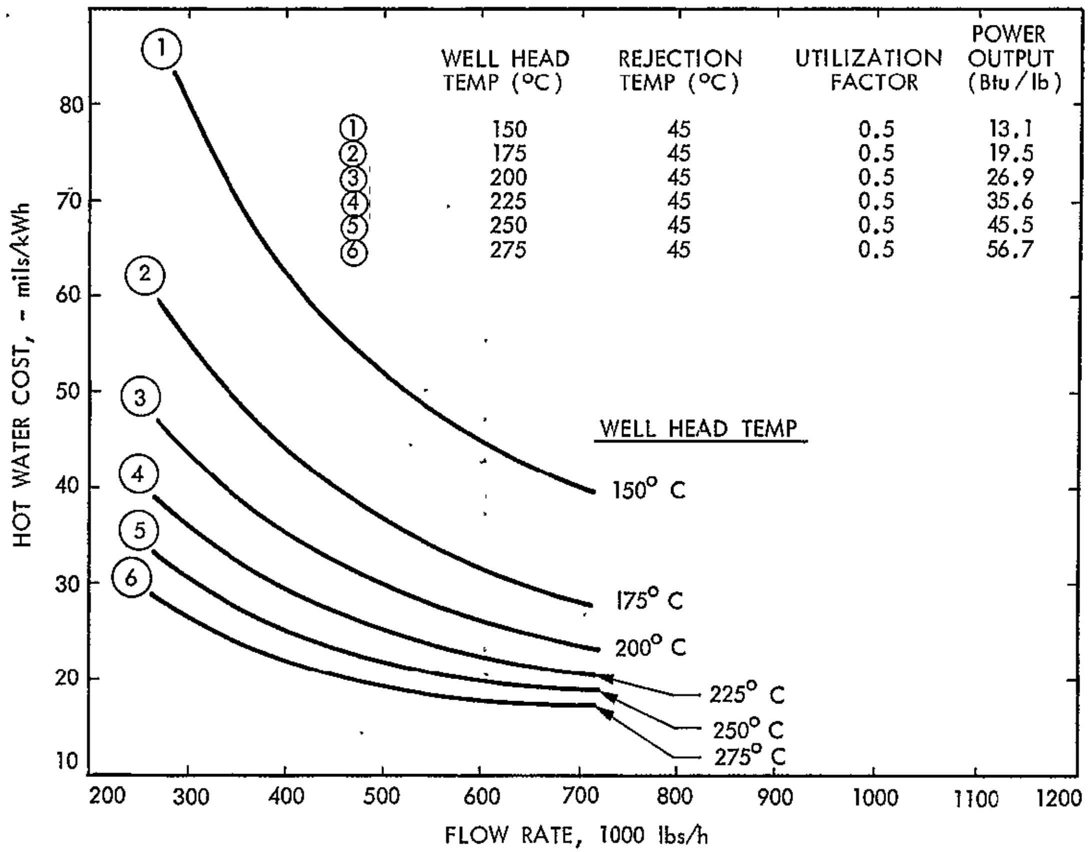


Figure 2-2. Resource Price Assuming Well Cost of $600,000 Per Well

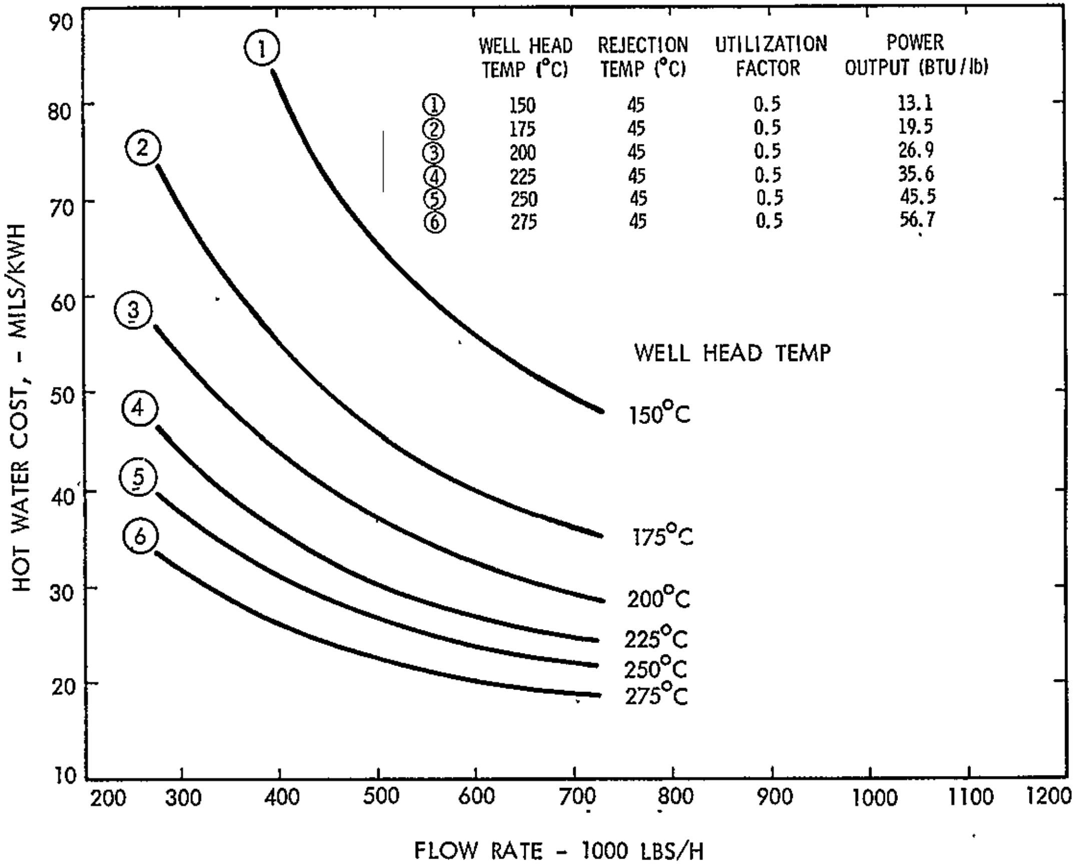


Figure 2-3. Resource Price Assuming Well Cost of $800,000 Per Well

Table 2-2. Geothermal Energy Cost of Power Assumptions

	Temp, °C	Flow Rate klb/h	Power Plant Cost $/kW		Field Cost K$/well	Cost of Power mills/KWh
Salton Sea, Brawley	300	500	Low	500	500	33
			High	750	700	45
Mono-Long Valley Coso Hot Springs Lassen	220	500	Low	500	600	42
			High	750	800	55
Heber, East Mesa	190	500	Low	500	400	40
			High	750	600	56
Geysers Hot Water Glass Mountain, Diablo	200	500	Low	500	600	46
			High	750	800	62
Surprise Valley Wendel-Amadee	175	500	Low	500	600	54
			High	750	800	71

are not yet confirmed by deep drilling, and in the other areas well data is held proprietary, these estimates are perhaps better described as guesses, but they serve a useful illustrative purpose.

The assumptions used are presented in Table 2-2, and the estimates derived from them are shown in Figure 2-4. Clearly, based on these assumptions, none of the hot-water resources are presently competitive with the other energy alternatives. Given the assumptions of Table 2-2 prove valid, the cost of hot-water electric power will have to be reduced at least 10% to bring any hot-water resources to a competitive price, and by as much as 58% to bring all of the estimated resources into the competitive range.

2. Potential Actions to Reduce Costs

The cost of electric power produced from geothermal resources is determined by a number of factors, including most prominently:

(1) Power plant cost.

(2) Cost of field discovery.

(3) Cost of field development.

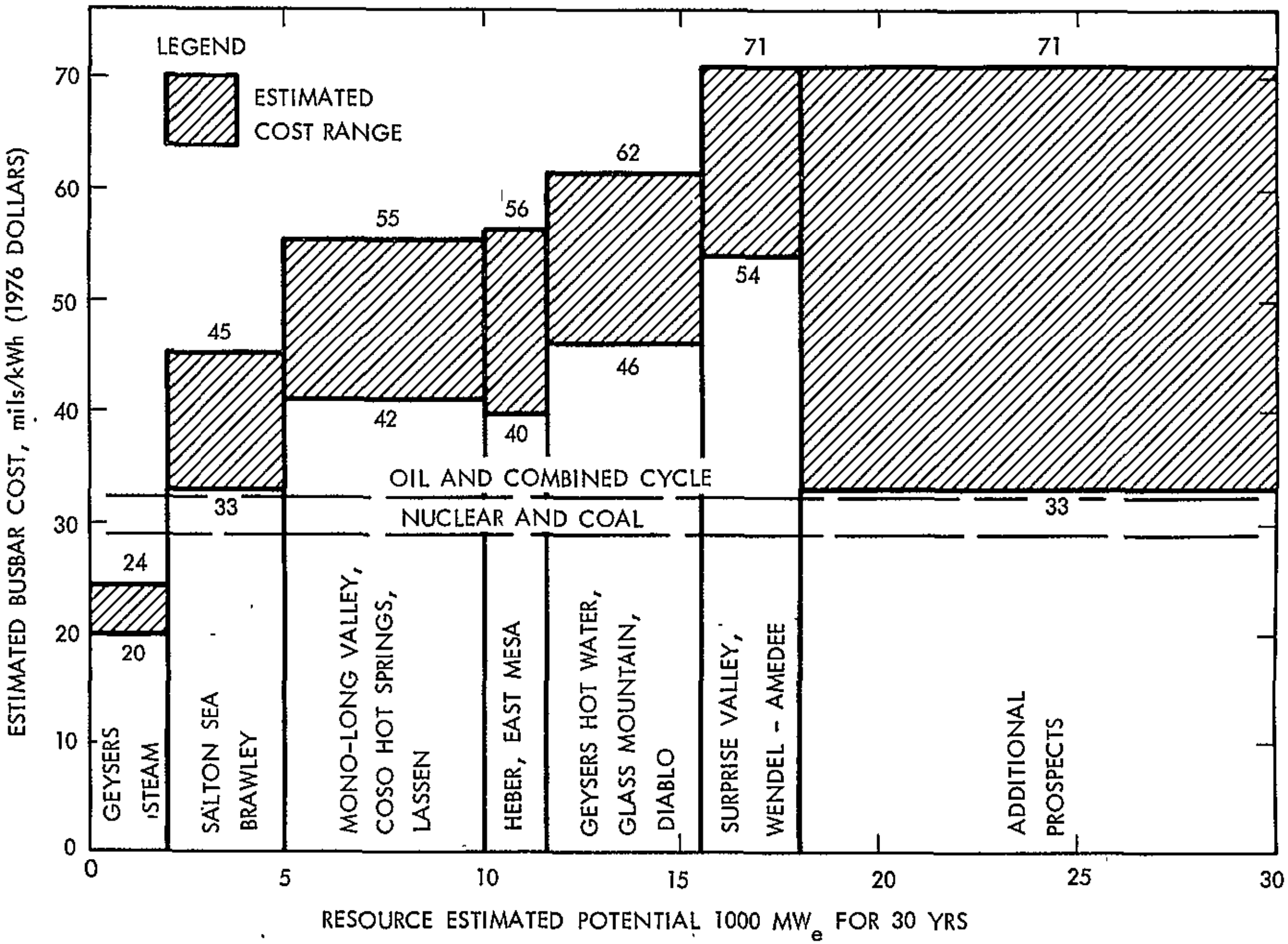


Figure 2-4. Estimated Current Cost of Geothermal Power

(4) Tax treatment of these costs.

(5) Tax treatment of revenues.

(6) Operations and maintenance cost.

(7) Plant availability factor.

(8) Investor rate of return.

Various action alternatives are available. They include reducing the basic costs themselves through improved technology, or reducing the impact of those costs on the price of power through tax treatment of costs and revenues and investor rate of return. These alternatives have varying lead times, price tags, effectiveness in stimulating investment in geothermal enterprises, and probability of success. A discussion of these alternatives follows.

a. Reducing Power Plant Costs. Power plant costs, according to the SRI report (See Reference 2), can be expected to be about 40-45% major machinery costs, and 55-60% in engineering, field construction, and miscellaneous items such as piping, electrical wiring, meters and controls, etc. The latter costs are unlikely to be affected by R&D activities. Machinery costs could conceivably be reduced by the development of improved components, but until a plant is built and operated, true costs will not be known, and the impacts of hypothetical improvements will not be readily assessable. Consequently, R&D aimed primarily at reducing power plant capital cost in itself is likely to prove ineffective in influencing present conceptions of the future cost of geothermal power, and therefore present investment decisions.

b. Reducing the Cost of Field Discovery. The costs associated with discovering and proving out a geothermal field are estimated to contribute no more than 10-15% of the eventual cost of power. R&D efforts to improve exploration and reservoir assessment technology, while important for other reasons such as increasing investor confidence, or reducing regulatory agency workloads, cannot have more than a minor direct impact on the cost of power.

c. Reducing the Cost of Field Development. The cost of field development is a major contributor (30-50%) to the cost of power, and is amenable to reduction in a number of ways:

(1) Increased power-plant cycle efficiency would reduce the number of wells required to support a power plant. R&D on improved heat exchangers, prime movers, and condensers could increase cycle efficiency as much as 20%, with a corresponding reduction in the number of wells required. Such technology will be expensive to develop and demonstrate on a commercial scale, and would probably not see commercial use before 1985.

Post-1985, it should play a major role in making marginal fields economically attractive.

(2) Increasing the flow rate per well would also reduce the number of wells required to support a power plant. Where well flowrate is limited by formation permeability, well stimulation techniques can be developed. R&D efforts are being directed toward their development. Stimulation of Geothermal wells is a unique problem, however, quite different from oil well stimulation, and the date such techniques might become available is difficult to predict. Where well flowrate is instead limited by choking in the borehole, development of suitable down-well pumps may provide a solution. DOE has been actively developing such pumps, and one has already been tested at Heber. It would not seem overly optimistic to count on the availability of such pumps by the early 1980's.

(3) Decreasing the time required for drilling would proportionately reduce the intangible element of drilling costs, estimated to be 50% to 70% of the total cost of field development. Improved drill bits, muds, and associated equipment can be developed within the R&D program, and would reduce drilling time. These improvements could be available by the early 1980's.

(4) Decreasing the manpower required through automation of the drilling process would have a similar effect on the cost of field development. Such a development would be difficult and expensive, and, if pursued, would probably not be available for widespread use before the late 1980's or 1990's.

R&D efforts are ongoing in almost all of these areas. While it is difficult to schedule advancements in technology, it is a reasonable assumption that, if the R&D program is vigorously pursued, a 20% reduction in field development cost should be achievable by the early 1980's, and a further 20% reduction by the late 1980's.

d. Changing the Tax Treatment on Costs. The allowance of the intangible drilling cost write-off for geothermal wells has the immediate effect of reducing that portion of the cost of power attributable to field development by 14% to 21%, depending on the percentage of the total cost written off. (Fourteen percent corresponds to fifty percent, twenty-one percent to seventy percent intangible.) This measure is particularly attractive in that it provides more capital for exploration and is an important step in making geothermal energy resources competitive with other energy resources.

e. Changing the Tax Treatment on Revenues. Provision of a 22% depletion allowance for geothermal wells has the immediate effect of reducing that portion of the cost of power attributable to field development by about 17%, assuming a corporate income tax rate of 48%.

f. Operations and Maintenance Costs. Operations and maintenance costs represent 10-15% of the estimated cost of power. It is not anticipated that R&D will significantly impact these costs.

g. Plant Availability Factor. The cost of power is inversely proportional to the availability factor. Any increase in the availability factor directly reduces power cost. What the availability factor will be, however, will not be known until some operating experience with commercial geothermal power plants is obtained. R&D on the chemistry and mechanics of scale formation and scale control, on components and materials with improved lifetimes in geothermal environments, on scale removal, and on other related areas can be expected eventually to bring this factor up to the 80% range presently experienced at the Geysers. The present uncertainty in this factor is a major deterrent to utility commitment to hot-water geothermal power plants, (and a major argument for the need for a cost shared demonstration plant).

h. Investor Rate of Return. The rate of return required by an investor is a major factor in the cost of power. In the case of the utilities, this is set by the Public Utility Commission (PUC). In the case of the field developers it is not rigid, but will vary according to the perceived risk of the enterprise, and the rate of return available from alternative investments. Most projections of the cost of geothermal power assume a 20% rate of return required on developer investments; this reflects a relatively high perception of risk. The actions discussed that tend to reduce the risk associated with geothermal investment and increase confidence will have some influence on the acceptable rate of return. If the acceptable rate of return could be reduced to 15%, it would decrease the cost of geothermal fuel by about 25%.

3. Program Recommendations

Until industry perceives that there is a reasonable probability that the hot water resources will become competitive there will be little effort to commit to their use or to expand exploration activities. This is the situation today! However, referring to Figure 1-5, there must be a rapid increase in exploratory drilling in the remainder of the 1970's and extending into the 1980's to support the growth scenarios postulated. This must be followed in two to three years by increasing utility commitment. The President has proposed tax incentives to encourage the development of geothermal energy. In addition, there are a number of R&D programs underway to improve both extraction and utilization technology. These various actions offer the promise of making geothermal energy competitive with alternative sources of energy in the 1985 time frame. To this end the following program to reduce the cost of geothermal energy is proposed:

1978: Provide the Intangible Drilling Cost Write-off
This would have the effect of reducing the cost of power (Figure 2-4) range of the hot-water resources from 33-71 to 31-63 mills/kWh

and Provide 22% Depletion Allowance
This would have the effect of further reducing the cost of power range to 29-57 mills/kWh.

These two actions are now being considered by the Congress. The effect of these two measures, shown in Figure 2-5, is to reduce the fuel related cost by 25 to 30% and make a considerable reduction in the cost differential between geothermal energy and the competing sources of energy. These incentives, in 1978, will be particularly effective stimuli and provided capital for the increased exploration beginning in 1978 which is necessary to support the rapid growth in utilization in the mid 1980's. These incentives in 1978 will also provide a clear signal to industry that the federal government is committed to the development of the nations geothermal resources.

1980-82: Reduce Field Development Cost by 20%
This may be accomplished by a combination of technology developments under way by DOE including down-well pumps to improve well flow rate and improved drill bits, which would reduce drilling time and material cost. The effect of these developments would be to decrease the cost range to 27-52 mills/kWh.

1983-85: Reduce Field Development Cost by 20% More
This could be accomplished by a combination of technology developments which would include:

(1) Improved heat exchangers, prime movers and condensers to improve cycle efficiency and decrease the number of wells required.

(2) The development of well stimulation techniques to improve the flow rates of marginal wells.

(3) The development of advanced down well pumps. The total effect of the developments would be to further reduce the expected cost range to 26-48 mills/kWh.

1985: Improve Power Plant Availability Factor
If the power plant availability factor could be raised to 0.8 the expected cost range would drop to 24-45 mills/kWh. This may be accomplished through R&D on the chemistry and mechanics of scale formations and control, improved heat exchangers and condensers, and improved material and component technology for the geothermal environment.

1985: Convince Investors to Accept a 15% Rate of Return
The effect of this action would be to reduce the cost range to 22-40 mills/kWh. As risk and uncertainty

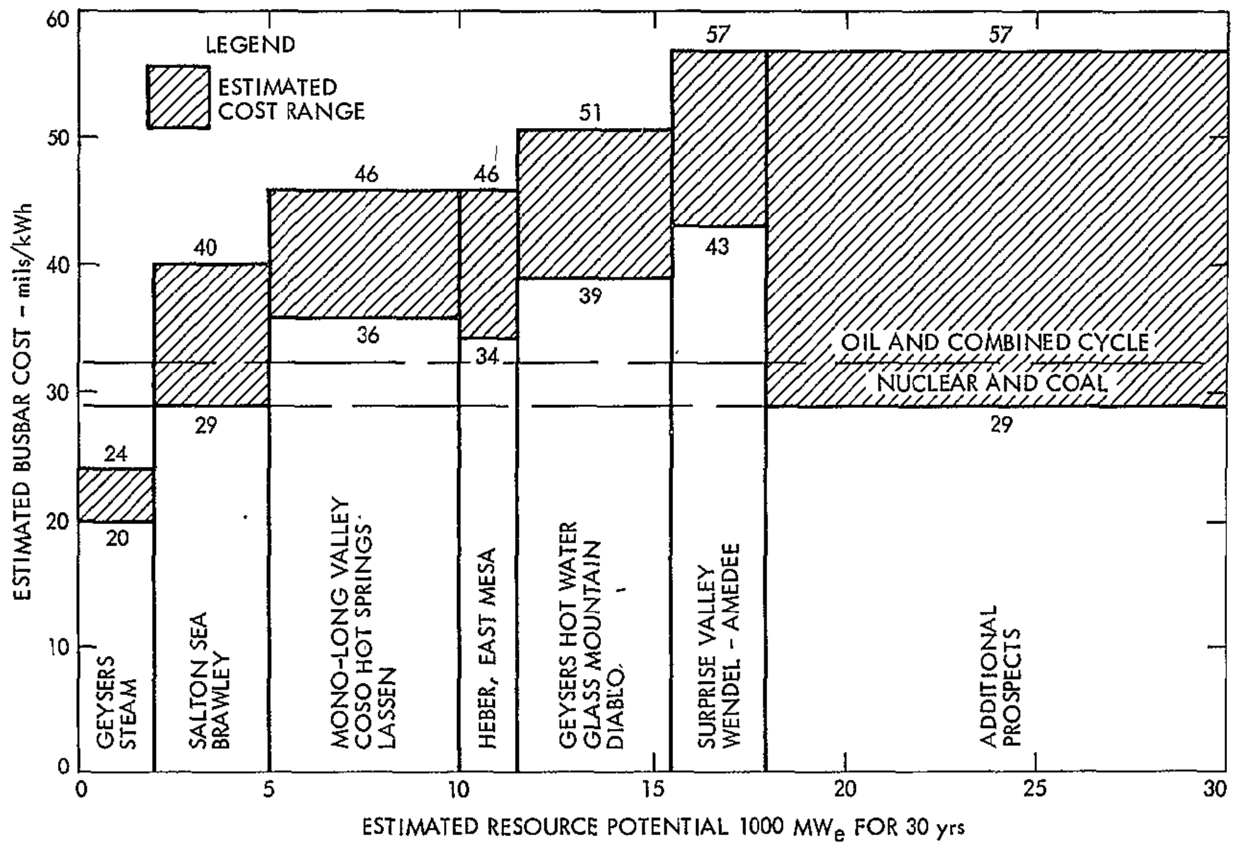


Figure 2-5. Effect of Tax Incentives on the Cost of Geothermal Power (1978)

decrease and experience and, more importantly, revenues increase (which would be implicit in the growth in geothermal postulated) such an action is quite likely.

If these actions have the expected effect, the cost of geothermal power, shown in Figure 2-6, would be very competitive with the alternative power sources in the 1985 time period. As previously discussed there is large uncertainty at this time on what will be the actual cost of power since no geothermal plant using the hot-water resources has been built and operated in the United States. As a result it is not known at this time if all or if only some of the actions recommended are required or which particular technology is required for a given resource. Those resource-specific needs which have been identified are presented in Section III.

B. REDUCING PERFORMANCE AND COST UNCERTAINTIES FOR POWER GENERATION FROM LIQUID-DOMINATED GEOTHERMAL RESOURCES

1. The Need for a Demonstration Plant for Hot-Water Resources

The technology and economics of power generation from dry-steam geothermal resources at The Geysers are well established. With the resolution of existing environmental concerns, it is expected that industry will move rapidly ahead with their plans for full development of the Geysers steam field by about 1985. However, there are considerable differences in the designs and operations of a geothermal plant using the relatively pure dry-steam resources and one using the hot water resources. First, hot-water contains less available energy per pound than the steam requiring more hot-water than steam for a given electrical output. Thus a plant using hot-water operates at lower efficiency and is much more sensitive to variations in well and component (i.e. heat exchangers, pumps, turbine, condensers, etc.) performances. Second, the dissolved solids in the hot-water present a much more severe corrosion and scaling environment which could reduce both component and well lifetimes and thus the plant availability factor. Third, the behavior of the reservoir is expected to be different from the "pure" steam field experience and much more subject to "plugging". There have been a number of design studies on the use of hot-water resources with wide variations in results. No commercial-scale generating plant has been built in the United States using these resources.*

As a result of the large performance and cost uncertainties associated with using the hot-water resources utilities are understandably reluctant to commit to their use without a full-scale commercial demonstration. Such a plant would have to be operational by 1981 to have the desired effect of providing the confidence base necessary to stimulate the utility commitments to geothermal energy beginning in 1982.

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*Foreign plants such as those in Mexico and New Zealand may be of some usefulness.

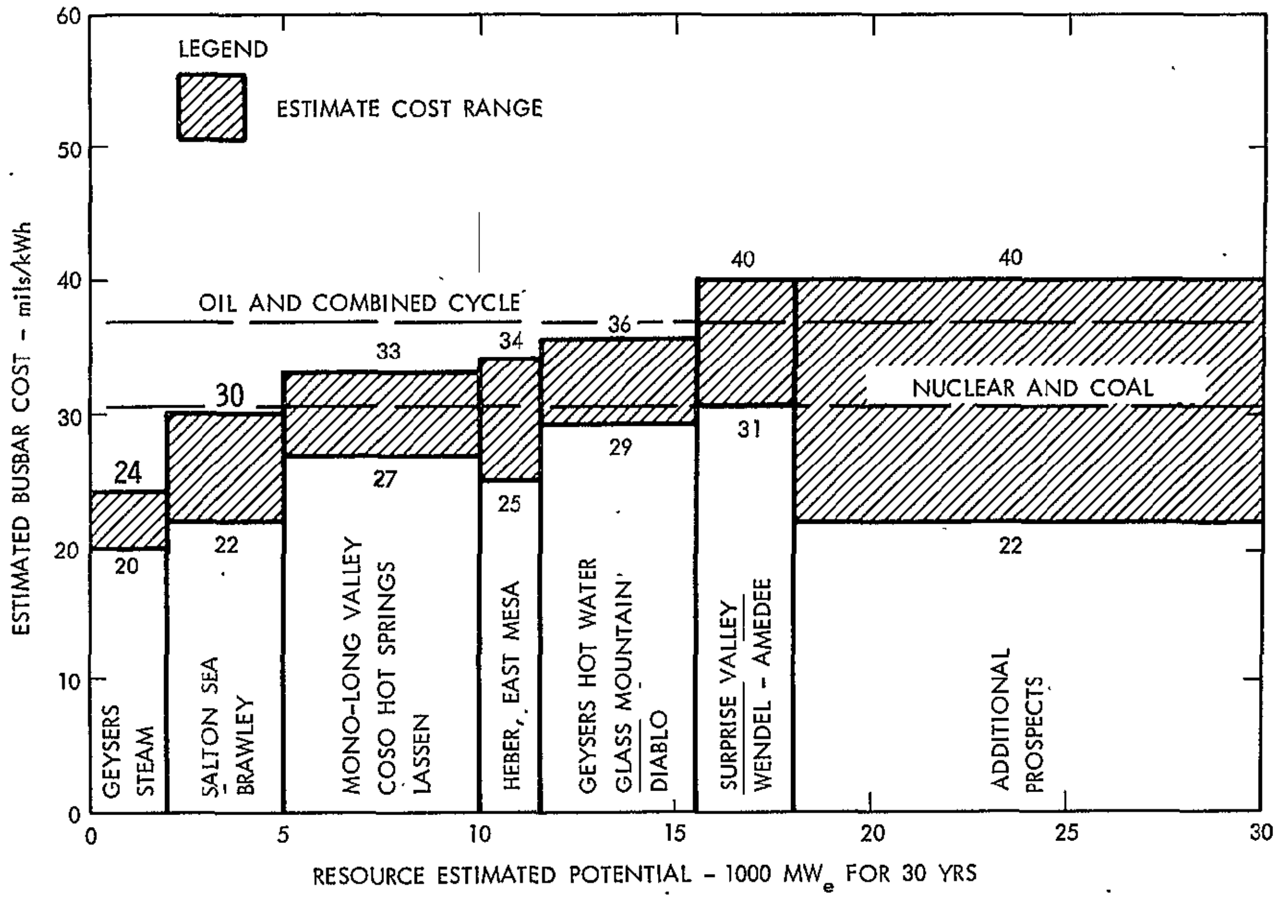

Figure 2-6. Estimated Future Potential Cost of Geothermal Power (1985)

2. Demonstration Plant Design Alternatives

There have been considerable differences of opinions on the technology that should be used for a hot-water plant; flashed steam or binary. The flashed steam process is the most commonly used around the world and is based on technology such as that demonstrated at The Geysers. The process is illustrated in Figure 2-7. A mixture of brine and steam from the production wells enters the high pressure flash vessel where the pressure is reduced causing an additional fraction of the brine to vaporize. The brine and steam are then separated. The brine enters a low-pressure flash vessel where the pressure is further reduced thus generating more steam. The remaining brine and cooling-water blow-down are then reinjected. The steam from the two flash vessels is introduced into a two-stage steam turbine and then is condensed. The condensate is pumped to atmospheric for use in the cooling tower. Performance uncertainties are based on such considerations as energy losses from in-well flashing of the brine and the effect of the corrosive brines (compared to pure steam) on component and turbine life time. High non-condensable gas content could reduce the cycle efficiency sufficiently to preclude the economic use of a flashed steam process.

The binary system, was conceived to get around the limitations of the flashed steam system. It uses the well flow to heat a separate, organic working fluid, such as isobutane, operating in a closed-loop Rankine cycle. Figure 2-8 shows the elements of the binary cycle. The hot-water is pumped to the surface to prevent in well flashing (and potentially large energy losses) circulated through the heat exchanger and reinjected into the reservoir. The heated working fluid is expanded through a hydrocarbon turbine, condensed and pumped back through the heat exchanger. Because the non-condensable gases are not circulated through the turbines they do not reduce turbine efficiency. The advocates of the binary process feel that the substantial down well pumping power requirements are more than offset by increased well flow rates and by much higher well head temperatures. Their studies show that the binary cycle is particularly promising for those resources with temperatures less than 200°C. It should be noted that the binary cycle involves more new technology than the flashed steam system and has yet to be demonstrated on a commercial scale (i.e., >50 MW_e) anywhere in the world. Critical new technology includes the down-well pumps, efficient heat exchangers and the hydrocarbon turbine.

3. Demonstration Plant Siting Considerations

For a plant to be operational by 1981 it must be built on a proven resource. Over the past two years Electric Power Research Institute (EPRI) has been sponsoring a series of studies for site selection and design options for such a demonstration plant. Their studies showed that adequate resource data existed only for Heber in the Imperial Valley in California and Valles Caldera, New Mexico. However, as a result of more recent development Roosevelt Hot Springs in Utah and East Mesa in the Imperial Valley could also be considered as potential sites. Both Valles Caldera and Roosevelt Hot Springs have temperatures greater than 220°C. Both are associated with volcanic structure.

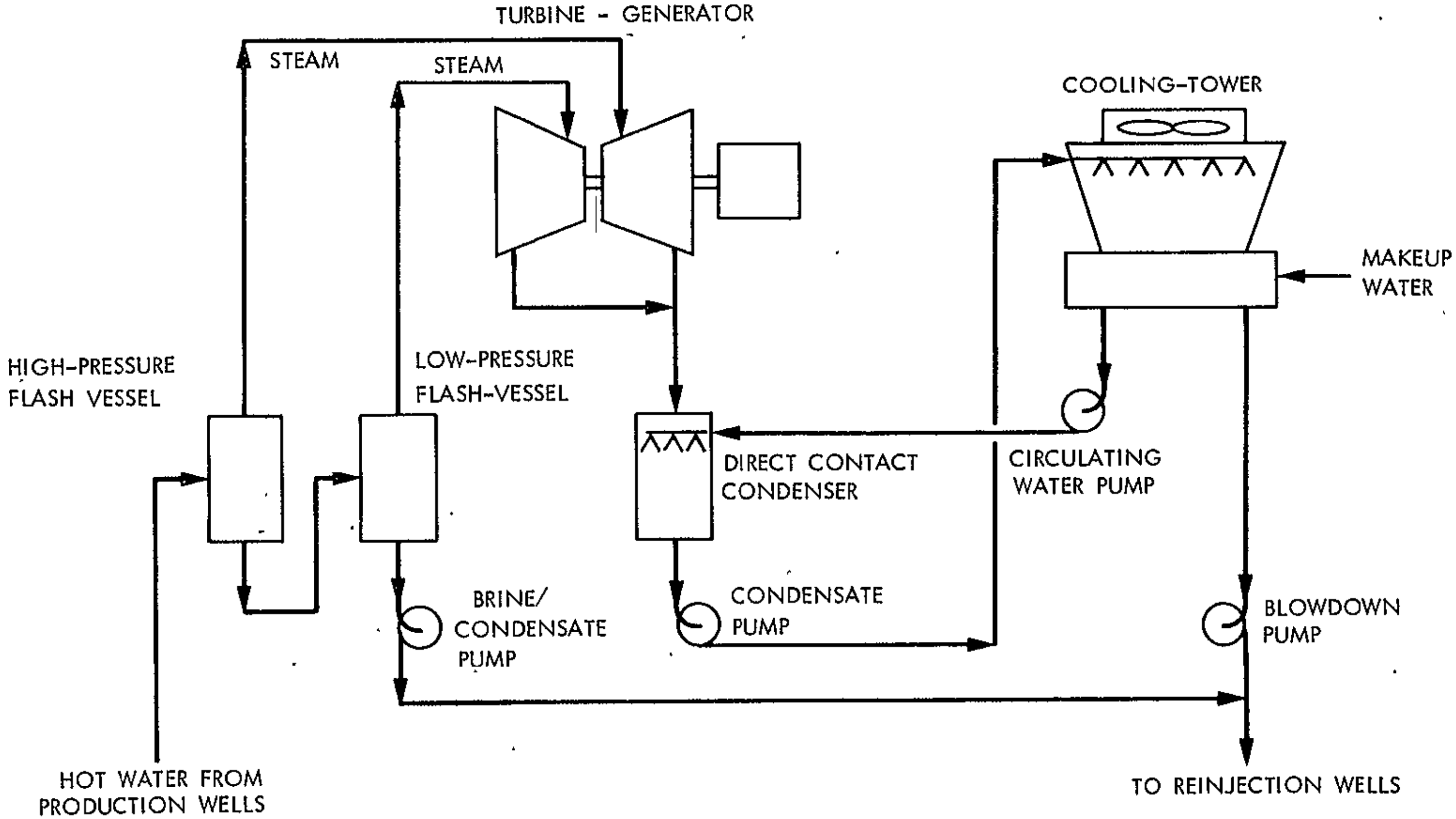

Figure 2-7. Two Stage, Flashed Steam Power Generation Process

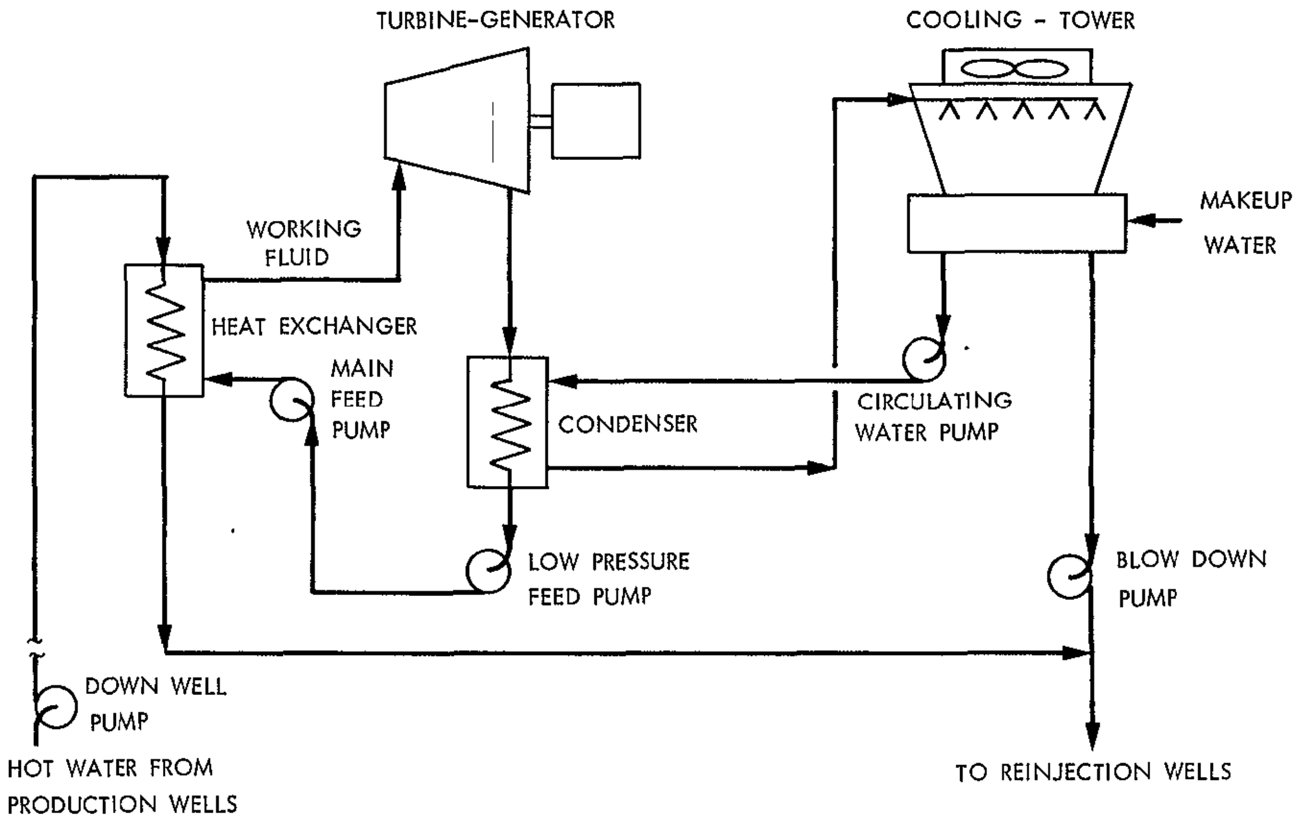

Figure 2-8. Binary Power Generation Process

On the other hand the temperatures of both Heber and East Mesa are near 190°C and are associated with sedimentary basins. Because of the differences in geologic structure and water temperatures it is questionable to what degree the technology and reservoir characteristics demonstrated at either Valles Caldera or Roosevelt Hot Springs would be applicable to the resource development in the Imperial Valley.* One of the difficulties with data correlation from site to site is that flashed steam technology could well be utilized at Roosevelt Hot Springs or Valles Caldera, while at the lower temperature of 190°C binary cycle technology would be required if the resource is to be economically competitive. The EPRI studies and subsequent analysis by SDG&E favor the binary cycle for Heber.**

4. Demonstration Plant Support Recommendations

The utilities have stated that a successful commercial-scale demonstration of power generation from hot-water resources is required before they will commit to the use of hot-water. Because of the differences in reservoir properties and required technologies for the available sites (i.e., Heber and East Mesa as compared with Valles Caldera and Roosevelt Hot Springs) a demonstration plant with the characteristics of East Mesa or Heber is critical to the rapid development of the hot-water resources in the Imperial Valley, The Geysers, and subsequently in the remainder of the state.

For the past two years EPRI has sponsored design studies which support the development of a 50 MW binary-cycle demonstrations plant at Heber in cooperation with the San Diego Gas and Electric Company. Figure 2-9 shows the SDG&E development schedule which could place it in operation by 1980. According to SDG&E analysis the cost of construction of a 50 MW demonstration plant and its subsequent operation over a five year period would be in excess of $100 million as depicted in Figure 2-10.*** During the early years of plant operation it is expected that there will be considerable periods of time when the plant will be shut down for repair, retrofitting and special tests. As a result the cost of power from the plant during the early years of operation will be in excess of 100 mills/kWh. As problems are resolved and the availability factor increases the cost of power will drop. The categories of risks that could affect the plant availability include:

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*The results from a demonstration plant at either Roosevelt Springs or Valles Caldera might be very pertinent geothermal developments at The Geysers, Long Valley or Coso Hot Springs which appear to be similar in resource characteristics.

**There is by no means unanimity on these conclusions, as Chevron favors two-stage flashed steam for Heber, Republic Geothermal favors the flashed steam technology at East Mesa.

***Note: The cost of field development is reflected in the fuel costs.

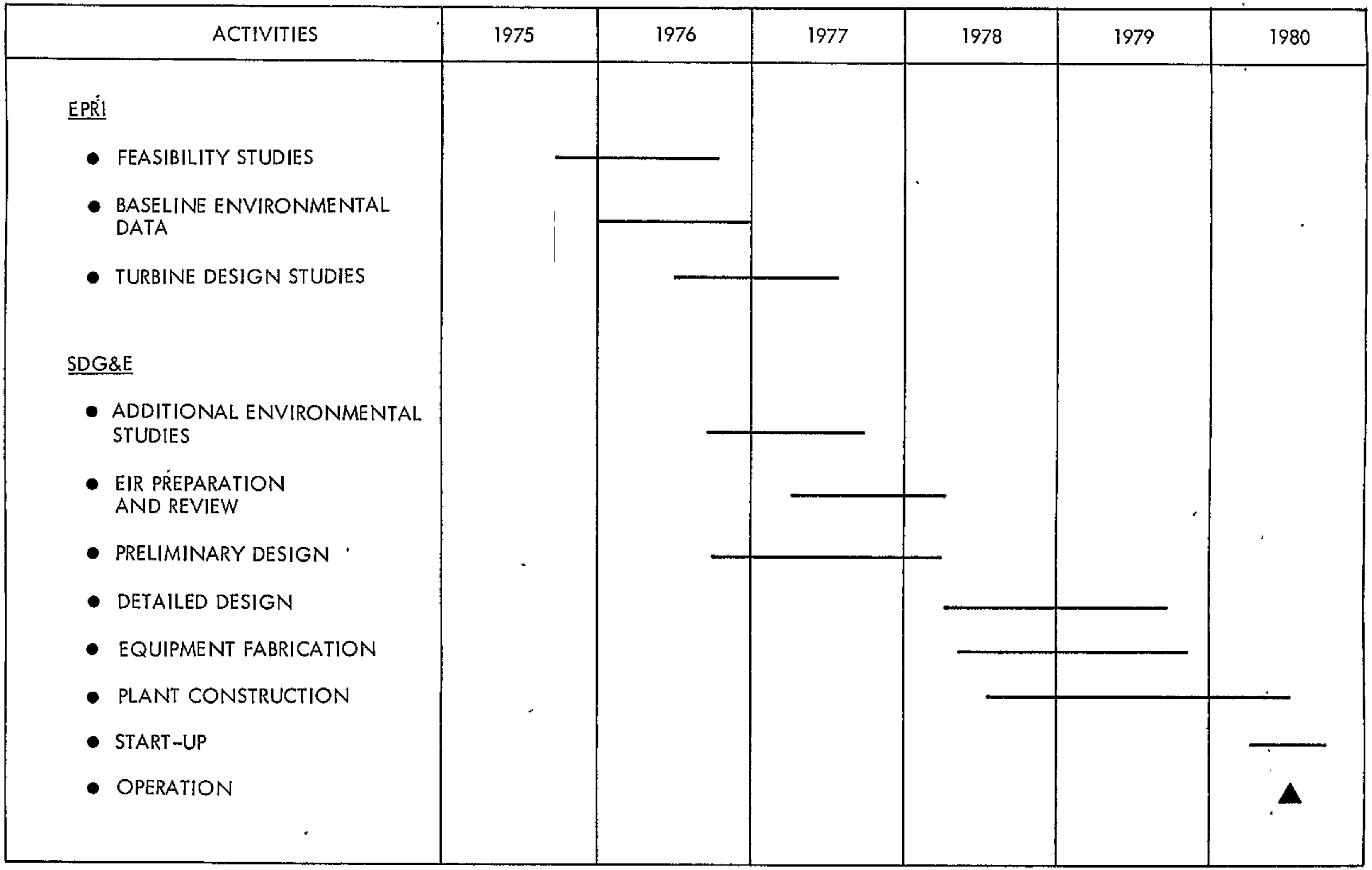

Figure 2-9. Heber Demonstration Plant Schedule (See Reference 7)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	TOTAL
CAPITAL										
POWER PLANT	1,314	16,410	14,408	9,050						41,182
TRANSMISSION			398	229						627
IDC	16	300	912	1,507						2,735
TOTAL CAPITAL	1,330	16,710	15,718	10,786						44,544
OPERATING COSTS										
FUEL				1,141	7,272	8,229	9,133	10,980	10,846	46,701
O & M				529	3,389	3,632	3,874	4,164	4,406	19,994
TOTAL OPERATING				1,670	10,661	11,861	13,007	15,144	15,252	66,695
TOTAL CASH REQUIREMENT	1,314	16,410	14,806	10,949	10,661	11,861	13,007	15,144	15,252	109,404

Figure 2-10. Project Cash Flow Heber 50 MW Geothermal Project ($ x 1,000)

(1) Brine supply

(a) Reservoir productivity.

(b) Well casings.

(c) Down hole pumps.

(2) Power Plant

(a) Turbine-generator development.

(b) Turbine-generator control.

(c) Organic working fluid containment.

(d) Scaling and corrosion.

(e) Extended start-up.

The magnitude of the investment, the poor economics, and the technical risks associated with such a plant are too large for any one utility to absorb in their rate base. SDG&E feels that it is essential to spread the costs and risks of such an undertaking over a wider segment of the public than their immediate customers since all electricity users stand to benefit from a successful demonstration of geothermal energy. For these reasons SDG&E is seeking support of up to 50% of the construction and operation costs of Figure 2-9 from the federal or perhaps state government. Possible vehicles for this support are:

(1) <u>DOE Demonstration Program</u>
The DOE FY-78 budget authorizes the support for one geothermal demonstration plant. However, the Heber demonstration would have to compete with proposed projects from other states.

(2) <u>Special Subsidy from the California Legislature</u>*
Because of potential importance of the geothermal option for California the state could authorize support of the project either by a special subsidy or through a state wide increase in electricity rates.

Joint state-federal sponsorship of the demonstration project would provide a clear signal, not only to the utilities but also to the exploration companies, that there is a serious commitment by both levels of government to establish the commercial viability of geothermal energy. Finally, as indicated in the SRI analyses, a government supported demonstration plant would have two pertinent effects:

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*Although no state monies have been committed the Legislature has demonstrated its support by forwarding to the Governor Senate Joint Resolution No. 12 which memorializes Congress and the President to establish a hydrothermal demonstration power plant at Heber, California.

(1) It would ensure that commercialization decisions are not delayed by unresolved uncertainty about future costs.

(2) It would alleviate the problem of asking electricity consumers in a limited area to bear the costs of demonstrating a new technology that will benefit a larger group.

C. STREAMLINING THE ENVIRONMENTAL REVIEW AND PERMITTING PROCESS

1. The Existing Process

a. Regulatory Requirements. The California Environmental Quality Act (CEQA) of 1970 and the National Environmental Policy Act (NEPA) of 1970 require environmental impact reports on any project which may have a significant effect on the environment. They require air and water considerations under the Federal Clean Air and Water Quality Acts; other environmental impacts also are covered including: Flora and fauna (covering endangered species), archaeological, errosion, roads, seismic and tsunami impacts, land subsidence, noise, etc.

Because geothermal energy must be utilized essentially in situ, the approval of the drilling of single well if successful implies the subsequent construction of a power plant. Thus, the application for drilling permits on private lands or the leasing of state and federal lands have caused the responsible local, state and federal agencies to prepare an Environmental Impact Report (EIR) under CEQA and an Environmental Analysis Report (EAR) or an Environmental Impact Statement (EIS) under NEPA. These reports consider not only the impact of the initial exploratory drilling project, but also the potential future development of a full power plant with the attendant total environmental review process.*

Environmental impact considerations may apply again at the time of exploratory or characterization drilling permits or at plant certification reviews.

b. Responsible Agencies. The environmental review and permitting processes involve a multiplicity of federal, state and local agencies as indicated in Table 2-2. In general, two levels and often three levels of government can be involved in the review and regulation of a

*On private and state lands the California Appellate Court has ruled that the EIR's on exploratory wells need not consider the impact of full development but just the environmental impact of the exploratory operations. On Federal lands the Forest Service and Bureau of Land Management are considering an approach which would allow applicants the options of a lease without a pre-lease environmental review with a stipulation that no surface occupancy can take place until the environmental review of such occupancy has been conducted.

Table 2-2. Public Agencies Involved in the Geothermal Resource Development Process

Jurisdiction Primary Area of Agency Interest	California	Federal	Regional or Local
Land Use	State Lands Commission	Department of the Interior Bureau of Land Management	County Planning Department
Operations Requirements: Enforcement	Division of Oil and Gas	Department of the Interior/ U.S. Geological Survey	
Air Quality Standards: Enforcement	Air Resources Board	Environmental Protection Agency	Local Air Pollution Control District
Water Protection: Discharge Requirements	State Water Resources Control Board	Environmental Protection Agency	Regional Water Quality Control Board
Fish and Wildlife Protection	Department of Fish and Game	Department of the Interior/ U.S. Fish and Wildlife Service	
Solid Waste Disposal	Solid Waste Management Board		
Water Resources Development	Department of Water Resources		
Forest Watershed Protection	Division of Forestry	Department of Agriculture Forest Service	
Intra-Governmental Coordination	Geothermal Resources Board	Geothermal Environmental Advisory Panel	
Pollution Control		Environmental Protection Agency	
Energy Research and Development: Conservation of Resources	State Energy Resources Conservation and Development Commission	Department of Energy	
Siting Approval of Power Plants: Rate Regulating	California Public Utilities Commission, CERCDC	Federal Power Commission	
Clearinghouse for Environmental Impact Reports	Governor's Office of Planning and Research		
Occupational Health and Safety Standards: Enforcement	Department of Industrial Relations	Occupational Safety and Health Administration	
Radioactive Waste Disposal Control	Department of Health		
Public Securities - Issuance and Trading Regulation	Corporations Commission	Securities and Exchange Commission	
Property Tax Assessment	State Board of Equalization		

The process of environmental review under the protective acts is relatively new and in many localities geothermal development is pioneering its application. It is not surprising that there are growing pains and some apparent confusion in its early use.

d. <u>Development Sequence</u>. Figures 2-11 and 12 show the general elements and associated timeflow of the power development process and the associated regulatory requirements for a geothermal plant on private and federal lands.

The general phases of the plant development cycle may be summarized as follows:

(1) Assessment and Land Acquisition

General geophysical assessments for likely prospects are made by industry or government followed by the acquisition of development rights. Environmental background data is collected and an EIR, EAR or EIS is prepared as appropriate for State, Federal or private lands. Following environmental review the land is leased (Federal or State) or exploratory drilling may start (private).

(2) Exploration

Drilling permits are obtained with appropriate review for exploratory drilling. For private land the EIR is approved at this time. Exploration deep-drilling proceeds. Usually several wells are required.

(3) Resource Characterization

Following a successful discovery, permits for resource-characterization drilling and testing are obtained. Drilling and testing proceeds to determine the magnitude and characteristics of the resource. Utility commitment for commercial resource development is sought.

(4) Plant Certification

The developing utility seeks approval of the power plant addition. Included are the Notice of Intent (NOI) and Application for Certification (AFC) reviews. Generally, detailed plant design and the application for the field development permits proceeds in parallel.

(5) Plant Construction

Production wells are drilled and the power plant is constructed.

given project. The public is involved and concerned at all steps with the right and power to act at any time through public and political pressure and through the courts.

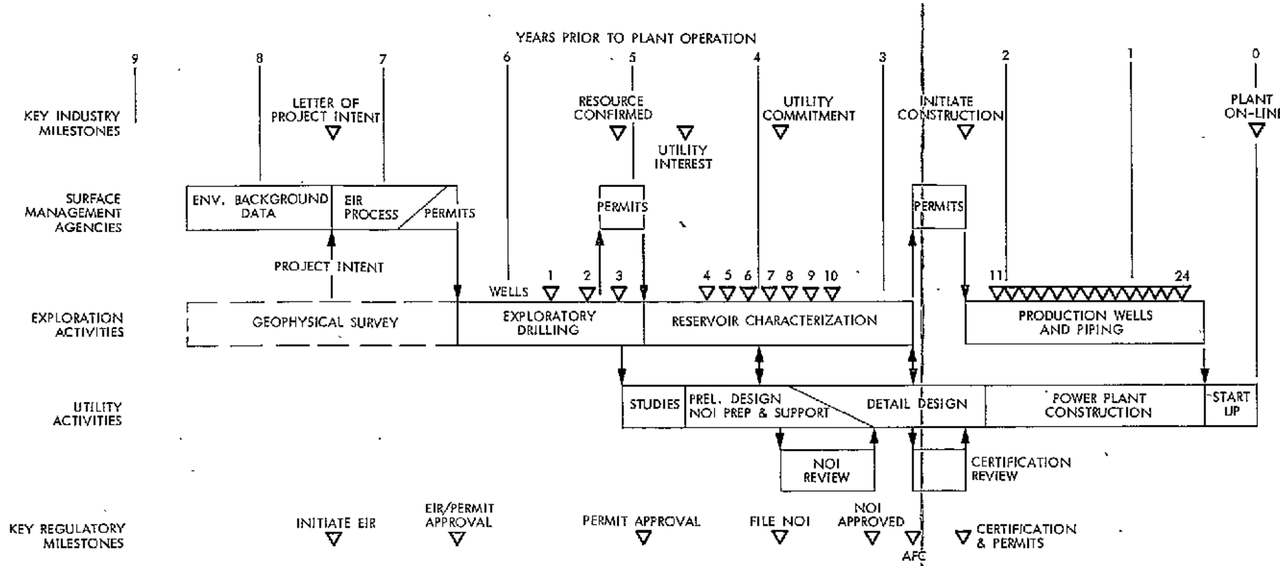
Environmental documents must be prepared by two lead agencies: one for the exploration phase and one for the power plant with review of the document by both responsible and "reviewing" agencies*. Responsible agencies are required by law to review and certify the document's adequacy. They apply their own standards and require specific information necessary to satisfy their own regulations and permit requirements. If a responsible agency does not accept the lead agency's environmental document, it can require the preparation of additional information and further public review before approving the project and issuing a permit. Ideally, early consultation between responsible agencies and the lead agency should eliminate this need. Reviewing agencies review and comment (only) on environmental documents from their own specific areas of expertise.

At the local level other interested parties including members of the resident community and environmental groups may review and comment on geothermal projects through the public hearing process.

Numerous permits, which also require interagency review, are also necessary in addition to the environmental document. The primary permits include: the county land-use permits; the local Air Pollution Control District (APCD), Authority to Construct and the Permit to Operate; Regional Water Quality Control Board (RWQCB) waste discharge requirements; and the various drilling permits for each phase of resource development.

c. Lead Agencies. For geothermal exploration on private lands the appropriate county acts as lead agency responsible for the preparation of an environmental document as a condition of its land use permit for a given project. For exploration on state lands, the State Lands Commission (SLC) has lead agency responsibility. On federal lands the managing land agency is responsible; primarily the BLM and USFS. Drilling permits and operations are the responsibility of the Department of Oil and Gas (DOG) on private and state lands the USGS on federal lands; they also require interagency review. The CERCDC is the lead agency for the construction and operation of geothermal power plants on state and private lands. On federal lands this responsibility may be shared between CERCDC and the appropriate federal agency.

*The lead agency has the principle responsibility for preparing environmental documents and for carrying out or approving a project which may have significant effect on the environment; responsible agencies have an "approval right"; reviewing agencies comment only. (See Tables 2-11 and 2-12).



AGENCY	REGULATORY ACTIVITY								
	BACKGROUND DATA	EIR PROCESS	EXPLOR-ATION PERMITS	EXPLORATION OPERATIONS	CHARACTER-IZATION PERMITS	CHARACTER-IZATION OPERATIONS	NOI REVIEW	CERTIFICATION & PERMITS	DRILLING OPERATIONS & PLANT CONSTRUCTION
STATE:									
CERCDC	**	*					P	P	
PUC							*	*	
DOG	**	**	P	P	P	P		P	P
DFG	*	*	*		*		*	*	**
OPR		**					**	**	
COUNTY:									
PLANNING COMMISSION	P	P	P	P	P	P	*	*	P
RWQCB	**	*	*		*		**	*	
APCD	*	*	*	*	*	*	*	*	*

LEGEND:
P = LEAD AGENCY
* = RESPONSIBLE AGENCY
** = REVIEWING AGENCY

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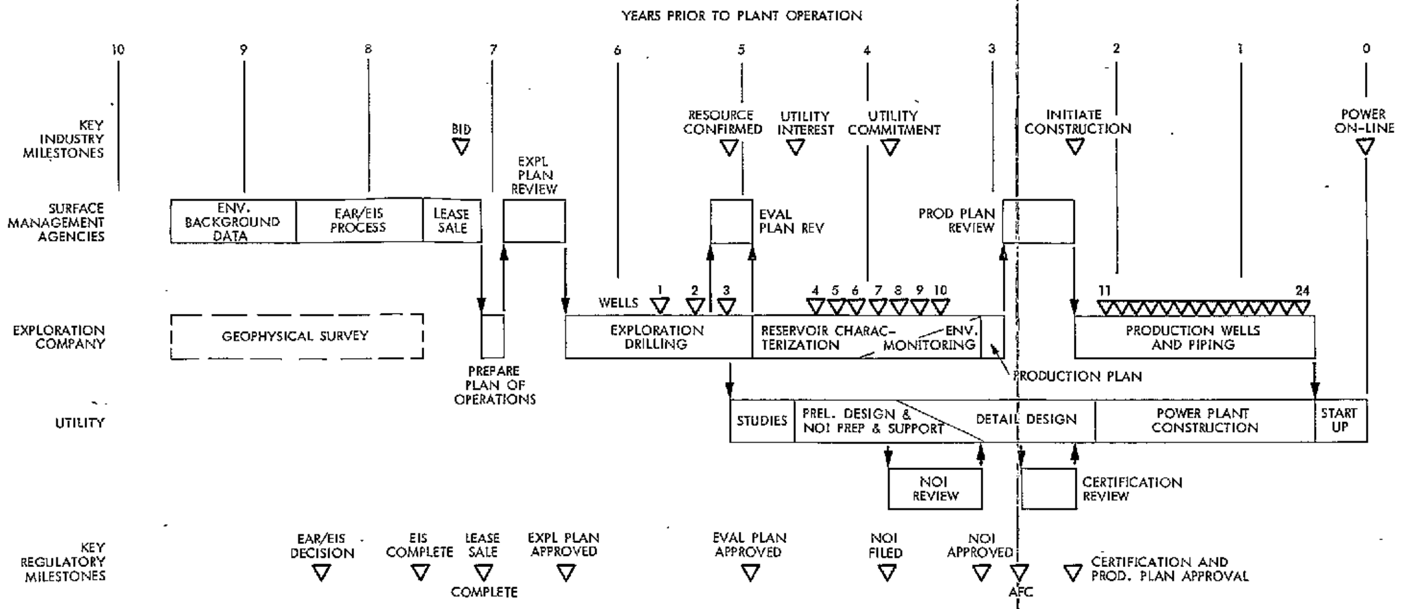
Figure 2-11. Geothermal Development of Private Lands (1st 50 MW_e (First Plant))

A

B



AGENCY	BACKGROUND DATA	EAR/EIS PROCESS	LEASE SALES	OP. PLAN REV.	EXPLORATION OPERATIONS	EVAL PLAN REV.	CHARACTER-IZATION OPERATIONS	NOI REVIEW	CERTIFICATION & PROD. PLAN REVIEW	DRILLING OPERATIONS & PLANT CONSTRUCTION
	REGULATORY ACTIVITY									
FEDERAL:										
BLM	P	P	P	*	*	*	*	P	*	*
USFS	(1)	(1)	**	*	**	*	**	*(1)	*(1)	*(1)
USGS	*	*	P	P	P	P	P	*	P	P
USFWS	*	*	**	*	**	*	**	*	*	
STATE:										
CERCDC		*	**					P	P	
PUC								*	*	
DFG		**		**		**		**		
OPR		**						**		
COUNTY:										
PLANNING COMMISSION		**	**	**		**		**	**	*
RWQCR	**	*		*		*		**	*	
APCD	**	*		*		*		*	*	

(1) USFS IS LEAD ON FOREST SERVICE LANDS

LEGEND:
P = LEAD AGENCY
* = RESPONSIBLE AGENCY
** = REVIEWING AGENCY

Figure 2-12. Geothermal Development of Federal Lands (1st 50 MW_e) (First Plant)

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Also shown in Figures 2-11 and 12 are the primary agency responsibilities for each of the development steps. The key regulatory steps are:

(1) The environmental review (EIR, EAR or EIS) and associated land use permits.

(2) Drilling permits for exploration.

(3) Drilling permits for characterization.

(4) Plant certification (NOI and AFC reviews), and drilling permits for production.

If the various reviews go smoothly (which generally has not been the case), the first plant can be brought on line in approximately 8.5 years on private lands and 9.5 years on federal lands. The exploratory drilling and plant construction require 6 years. The various approvals and reviews account for the additional 2.5 to 3.5 years. The approvals can and have taken even longer.

2. Permitting Delays

For various reasons the regulatory process is arduous and time consuming. It is cited by industry as one of the main causes for the lack of geothermal energy development today. They would like to see it streamlined. The following are some of the reasons for delay:

(1) Interagency Coordination

With the multiplicity of agencies there are questions of jurisdictional authority and certainly coordination associated with geothermal energy development. Each agency has responsibilities established by law. However, no agency has the duty or authority of coordinating the requirements of other agencies. This delay is manifested in both multiple agency reviews of single regulatory steps and in the differing requirements of the various agencies associated with a prospective development area.

(2) Agency Resource Limitations

The preparation of a complete and detailed EIR, EIS or EAR places a heavy load on the resources (both manpower and dollars) of the lead agency which can result in a delay in completion of the review. Lack of clarity in priorities can compound the resultant delays. On private land the delay will occur when applying for an exploratory drilling permit or alternately on application for characterization drilling; on state or federal land it will occur prior

to leasing or prior to characterization drilling.* The agency resource problem is compounded on Federal lands where the responsible agency may now be required to make a complete land management study of the entire area to be leased.**

(3) Limited Environmental Background Data

Environmental review has been hampered by limited data on the resource itself and its environmental effects.

(4) Unclear Requirements

In many cases the requirements of the various agencies are non-standardized, unclear and uncoordinated. Additionally, more data may be requested several times during the review process.

3. Impact of Permitting Delay

Even with the current low level of development in the state, the existing review requirements have saturated the limited staffs of the involved agencies and industry alike. However, if geothermal energy is going to be brought on-line at the rate postulated in scenarios, there will be a significant increase in lease applications, environmental reviews, drilling permits and notice of intent for power plant construction. Table 2-3*** shows the anticipated increase in the environmental review and permitting activities associated with the scenarios under the existing process. Clearly, if streamlining actions are not taken, the regulating process itself will be the factor that seriously constrains the geothermal energy growth rate.

For the most part industry is not seeking to avoid environmental requirements. Instead, they would like to see these requirements defined (and, if possible, standardized) so that they can take the necessary steps to comply and get on with their project. Most importantly industry is seeking assurance that these projects will be reviewed and acted on in a timely fashion. To this end members of industry have indicated that they would like to see some form of control over the regulatory process involving some or all of the following:

(1) Dealing with only one agency at each jurisdictional level.

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*See footnote page 2-32

**Federal Land Policy and Management Act of 1976

***Derived from the scenarios and the methods of Appendix B.

Table 2-3. Environmental Review and Permitting Activities

Milestone/Activity	Pre 1977	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
		Calendar Year													
Environmental Approval[1]															
• EIS's	-	4	2	5	1	3	7	1	1	3					
• EIR's	-	2	3	3	6	6	3	11	2	8	6	1		1	
Total		6	5	8	7	9	10	12	3	11	6	1		1	
Drilling Plan Review[2]															
• Operation Plans	-	2	6	9	10	33	16	13	36	20	19	28	31	31	32
• "P" Reports	-	5	6	10	13	19	18	28	21	33	33	26	21	24	10
Total		7	12	19	23	52	34	41	57	53	52	54	52	55	42
Wells Drilled															
• Exploration & Characterization	-	23	32	58	55	87	148	114	167	232	176	173	162	199	126
• Production	-	26	24	14	49	63	69	85	120	161	225	285	328	388	427
• Total	48	49	56	72	104	141	205	177	263	365	377	452	480	497	526
Utility Filing[3][4]		3	4	5	4	8	10	13	18	19	25	27	28	28	28
Power Added															
• Units Added			2	2		3	4	5	4	8	10	13	18	19	25
• MW_e Added			161	245		270	320	370	320	460	560	650	200	950	1250
• MW_e Cumulative	502		663	908	908	1178	1498	1868	2188	2648	3208	3858	4758	5708	6958

(1) Assumes EIS's for each lease block and EIR's for full field development (i.e. 5000 acres) rather than for individual projects which would increase the number of environmental documents.
(2) Operation plans are required for approval of drilling operations on federal lands and "P" reports for state and private lands.
(3) Utility filing initiates plant approval (NOI) and certification (AFC) process.
(4) Assumes 50 MW_e additions for hot water.

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(2) Each agency with geothermal jurisdiction to "show cause" why they should have such jurisdiction.

(3) Institution of a maximum time limit for processing permit applications, with extensions only for cause.*

(4) A clear definition of data requirements.

(5) Concurrent permit application processing by each geothermal entity.

4. Permitting Program Recommendations

There is a general recognition and desire by the parties involved, both the agencies and industry, that the problems with the current regulatory-permitting process should be resolved. In November of 1976 the first step to this end was taken by the convening of a State-Federal Geothermal Regulatory Interface Workshop at Asilomar, California. Representatives of industry and local agencies also were in attendance. Topics covered included environmental reviews, well-operations, power plant siting, non-electric projects and water and air quality regulations. The workshop developed recommendations on improving the permitting process (Reference 10).

Based on the results at Asilomar, two classes of actions are recommended: one directed at streamlining the permitting process and the second directed at developing the environmental data and criteria necessary to speed evaluation of the proposed projects.

a. Streamlining. First, it must be recognized that the agencies now involved in regulating geothermal development generally have jurisdictional authority and responsibility, established by law. As a result, the off-times proposed, one-stop permitting process is not feasible. Streamlining the process, if it is to occur, must be based on the knowledgeable co-operation and consent of the responsible agencies. To this end it is proposed that a joint state, federal inter-agency permitting project be established with the goal of reducing total regulatory time delay associated with the complete development process (re: Figures 2-11 and 12) from 2.5 to 3.5 years to less than 1 year.

A general outline of the program plan for this effort would be as follows:

(1) Defining and codifying the existing process (both written regulations and actual practice and concerns).

*California has passed AB 884 which establishes time limits for decisions by responsible agencies.

(2) Evaluating means of streamlining the process using the mutual efforts of industry, government agencies and the public. Their cooperation and consent is crucial.

(3) Seeking inter-agency agreements on operations, criteria and standards to minimize regulatory and jurisdictional conflicts.

(4) Preparing analyses of alternatives and recommendations on streamlining the process which identify the effect of changes in laws, regulations, procedures, standards, etc.

Recognizing that it is possible to change the process but not improve it, care must be exercised to retain those processes which are finally working after the adjustment to the CEQA and NEPA requirements.

b. Environmental Data. The second set of actions are directed at gathering the environmental data necessary to evaluate the potential impact of the proposed development in a timely fashion. Development is paced by the need to gather the necessary environmental baseline data which takes on a year or more. Imperial County presently is completing a two year project directed at gathering the necessary baseline and environmental effects data which will allow them to act on geothermal developments without additional major delays. The four counties at the Geysers have requested federal government support for a two year program in that area. It can be anticipated that other areas will have similar needs. The cost of gathering the necessary environmental baseline data is high and generally beyond the means of local agencies. It is recommended that the state and federal government subsidize the gathering of much of this data.

Finally, because of the need for environmental effects data throughout the state, it is recommended that a centralized source of geothermal environmental data be established and charged with the responsibility of gathering, indexing and distributing data from published reports, EIRS, etc. A centralized source will be effective only if it is responsive to user needs and can supply the needed data in the form required for timely decision making by the regulatory agencies.

D. ACCELERATING THE LEASING OF FEDERAL LANDS

1. Current Leasing Status

Timely access to the potential geothermal resources on federal lands is important to the state. Of the 1,400,000 acres of KGRA lands within the state 55% are under federal jurisdiction as is indicated in Table 2-4. It is estimated that the largest fraction of the states' geothermal potential and many of the more promising sites are on these federal lands. In the Geothermal Steam Act of 1970 Congress provided for geothermal leasing and development of federally administered lands. Under the act those lands associated with KGRA's are subject to competitive lease sales; the remainder to non-competitive leasing. However, the

Table 2-4. KGRA Land Classification (Jan. 31, 1976)

KGRA	Total KGRA Area (acres)	Private, State & Other	Federal Lands (Subject to the Act): BLM[1]	Forest Service	Other
THE GEYSERS REGION					
Geysers-Calistoga	378,687	296,268	76,748	5,671	0
Knoxville	14,702	5,107	9,595	0	0
Little Horse Mtn.	1,188	0	0	1,188	0
Lovelady Ridge	6,887	1,239	3,090	2,558	0
Witter Springs	18,152	13,663	4,489	0	0
Subtotal	419,616	316,277	93,922	9,417	0
IMPERIAL VALLEY REGION					
Brawley	28,885	28,885	0	0	0
Dunes	7,680	0	0	0	7,680[2]
East Mesa	37,565	4,840	0	0	32,725[2]
Glamis	25,505	2,080	0	0	23,425[2]
Heber	58,568	58,568	0	0	0
Salton Sea	95,014	76,370	0	0	18,644[2]
Ford Dry Lake	7,687	520	7,167	0	0
Subtotal	260,904	171,263	7,167	0	82,474
EASTERN SIERRA REGION					
Bodie	640	0	640	0	0
Coso Hot Springs	51,760	8,430	16,690	0	26,640[3]
Mono-Long Valley	455,256	63,160	103,690	288,406	0
Randsburg	12,886	1,233	11,653	0	0
Saline Valley	3,200	0	3,200	0	0
Subtotal	523,742	72,823	135,873	288,406	26,640
NORTHEAST REGION					
Beckwourth Peak	2,558	0	2,558	0	0
Glass Mtn	33,502	901	0	32,601	0
Lake City - Surprise Valley	66,251	32,399	31,972	1,880	0
Lassen	78,642	24,002	0	54,640	0
Wendel - Amedee	17,292	13,312	3,980	0	0
Subtotal	198,245	70,614	38,510	89,121	0
CENTRAL COAST REGION					
Sespe Hot Springs	7,134	454	0	6,680	0
Totals	1,409,641	631,431 (44.8%)	275,472 (19.0%)	393,624 (27.9%)	109,114 (7.7%)

(1) Includes reserved minerals both before and after 1970.
(2) Bureau of Reclamation.
(3) United States Navy (China Lake). Status of such lands under the Act is under legal review.

leasing of these lands has been slow. Regulations implementing the Act became effective in January 1974. To date only 109,000 acres consisting of 60 tracts in four of the states' KGRA's have been offered for competitive lease sales. Bids have been received and accepted on 26 tracts consisting of 36,600 acres as indicated in Table 2-5. The KGRA lands leased are administered by the BLM; none are USFS lands. There have been 995 non-competitive lease applications in California; 287 have been rejected and only 10 issued.

The process of issuing a lease on federal lands can take on the order of 28 months as is indicated in Figure 2-13. A year is required to gather the necessary environmental background data for the lease block under consideration. Next an Environmental Analysis Report (EAR) is prepared, with appropriate federal agency input, which evaluates whether the proposed leasing and subsequent geothermal development would be done in keeping with established environmental and regulatory standards. In environmentally sensitive areas the EAR is generally <u>not</u> an adequate assessment and a more detailed EIS would be required. The EAR or EIS is then subject to public and further agency review and leasing stipulations prepared. This process determines <u>if</u> and where leasing of the lands included in the study area are to occur. (Normally only a fraction of the lands studied are offered for lease). With the approval of the EAR or EIS lease sales are then held. As has been the case to date the process can be drawn out substantially where potential leasing activities have been challenged by the public as well as by the reviewing agencies.

Table 2-5: KGRA Lease Sales Summary for California*

KGRA	Lands Offered		Lands Leased	
	Tracts	Acres	Tracts	Acres
The Geysers				
Initial offer (1/22/74)	12	8,750	10	7,950
Reoffer (5/29/74)	2	800	2	800
Mono-Long Valley (1/22/74)	7	13,700	3	5,500
East Mesa				
Initial offer (1/22/74)	14	30,200	5	9,200
Reoffer (6/4/74)	9	20,950	1	2,550
Surprise Valley (6/23/75)	16	34,600	5	10,600
Totals	60	109,000	26	36,600

*Data from USGS, Menlo Park

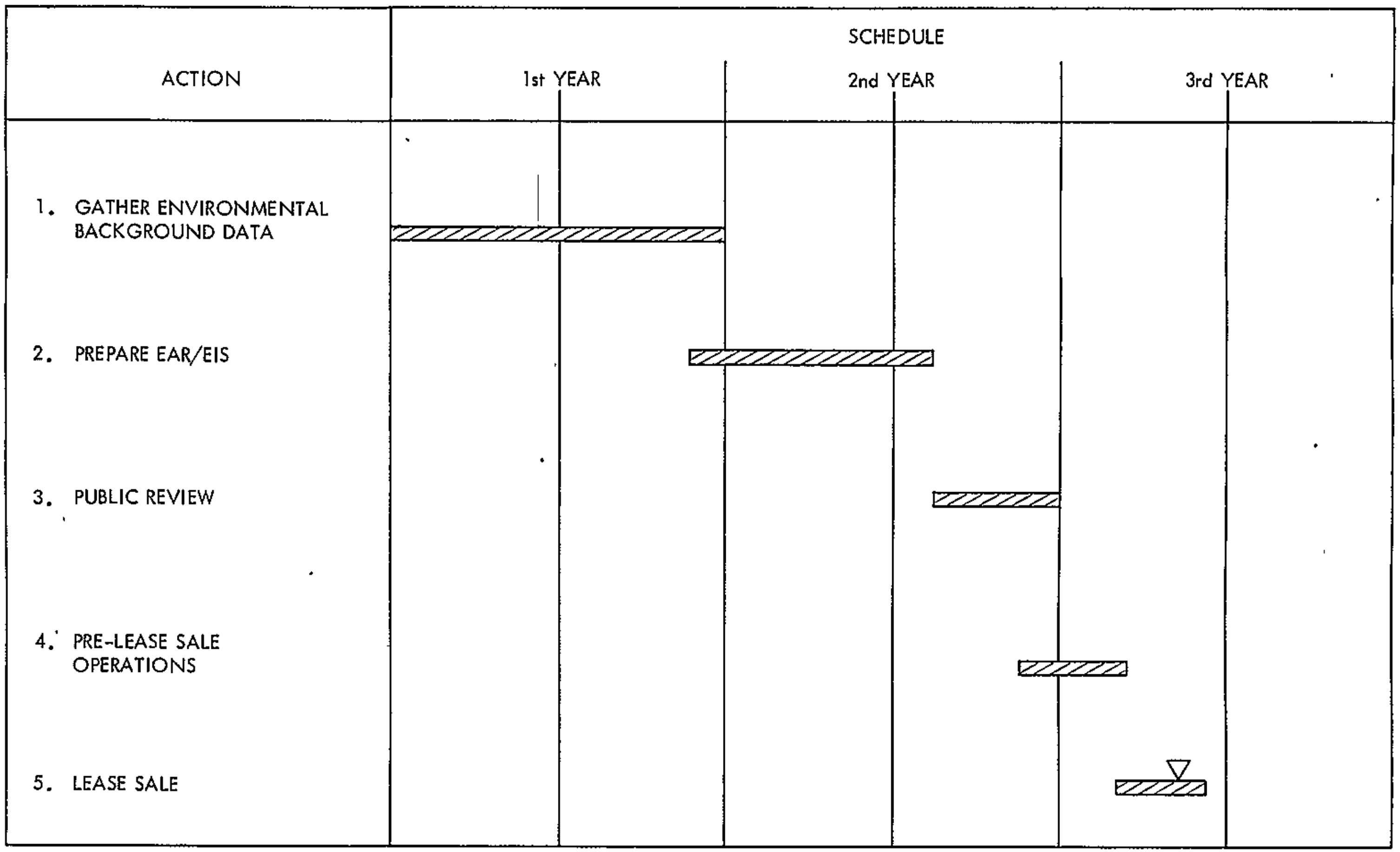

Figure 2-13. Lease Sale Process (Competitive Leases)

The leasing process is time consuming and requires a substantial commitment of manpower and money. Geothermal leasing is just one of many of the responsibilities of the two key federal agencies; the BLM and USFS. In addition, it does not seem to have high priority. As a result leasing is hampered by the limited staff and funding within these agencies.

2. Scenario Federal Leasing Requirements

Figure 2-14 shows the scenario-derived Federal leasing program requirements. Table 2-6 summarizes the leasing schedule requirements and associated acres.* The first priority sites includes those located primarily in the Eastern Sierra and Northeast subregions which are recognized as having large potential. Their development forms the basis for the large increase in geothermal power generating capacity in the post 1985 time period. Also included are 5000 acres of "homestead" lands in The Geysers steam field which have been until recently tied up in litigation and Bureau of Reclaimation (BUR) lands at East Mesa which are immediately adjacent to the Republic leases. The second priority sites includes those with undefined resource potential and those which are smaller in size. Their development would contribute to power on line in the post 1990 time period. At a recent meeting (Reference 11) with DOE and the BLM, USFS, and USGS the priorities and schedules derived from the scenarios were adopted as program goals.

Currently, there is an EIS being prepared for the Long Valley "grandfather rights" lands which are felt to be particularly rich in resource potential. The completion of this EIS on the schedule indicated could be placed in jeopardy by the requirements placed on the USFS to prepare a plan for total land use of national forests.** At Coso Hot Springs the BLM is working with the U. S. Navy on the leasing of these lands. Their schedule will have to be accelerated by six months to achieve the date indicated. The Forest Service will require financial assistance to complete the leasing activities at Glass Mountain and Lassen. The additional leasing at East Mesa probably can be conducted on the basis of existing environmental documents but will require the concurrence of the BUR. The EAR for Wendel-Amedee is currently in the review process.

3. Federal Leasing Program Recommendations

The timely leasing of the federal lands, particularly in the Eastern Sierra and the Northeast subregions, can be critical to establishing

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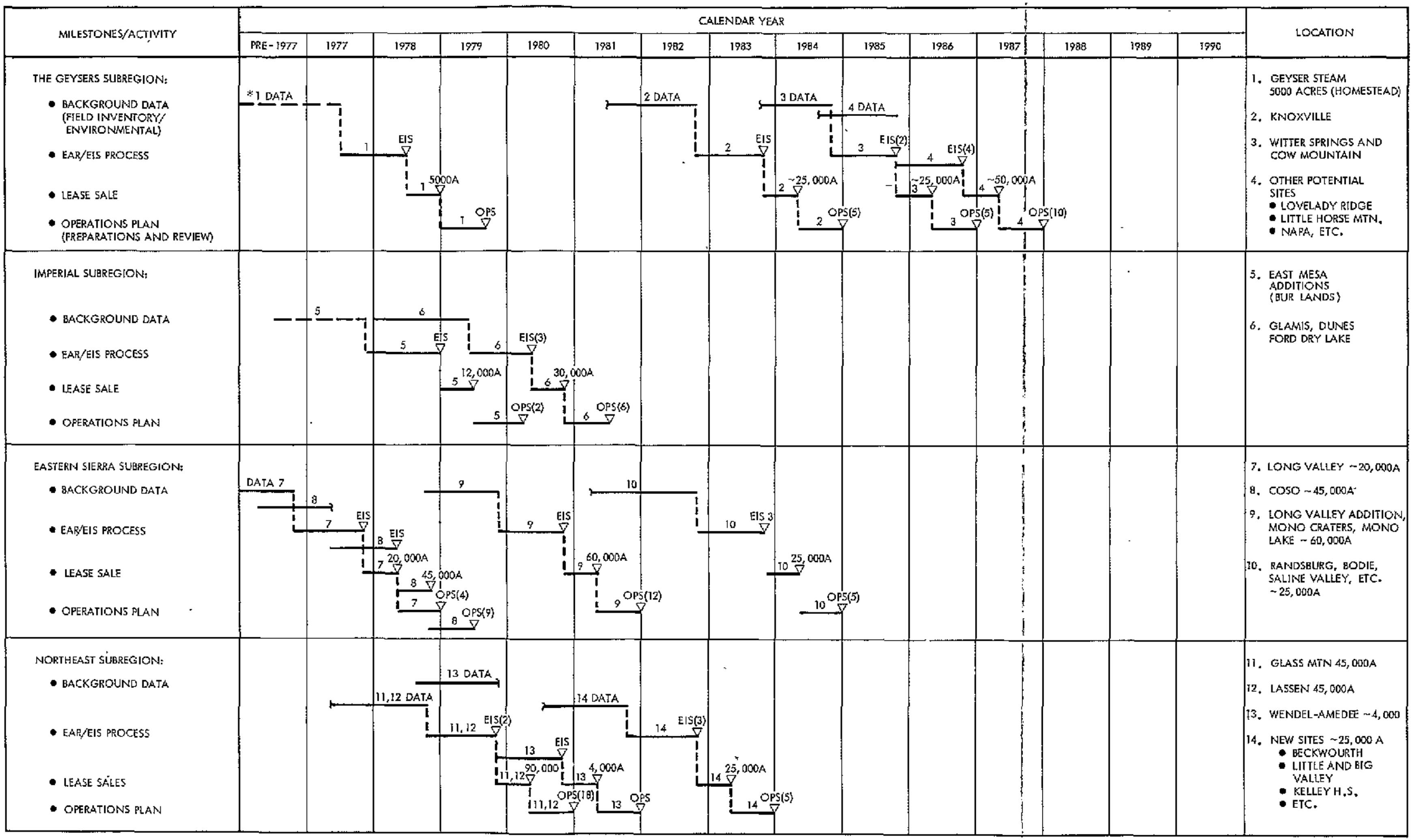
*Acreage requirements assume 2500 acres are required for each potential 200 MW_e sites and 10 potential sites are required for each successful site. On subsequent expansion on power resources it is assumed 5 potential sites are required for each successful site. (See Appendix B).

**National Forest Management Act of 1976 (PL 94-588).

Table 2-6. Scenario Federal Leasing Schedule

1st Priority	Req'd Lease Date	Req'd Acres
Long Valley "Grandfather" (USFS)	Apr 1978	20,000
Coso Hot Springs (USN/BLM)	Nov 1978	45,000
Geysers "Homestead Lands" (BLM)	Jan 1979	5,000
East Mesa Additions (BUR/BLM)	July 1979	12,000
Glass Mountain (USFS)	Apr 1980	45,000
Lassen (USFS)	Apr 1980	45,000
Wendell-Amedee (BLM)	Apr 1981	4,000

2nd Priority	Req'd Lease Date	Req'd Acres
Long Valley - Mono Additions (USFS)	Apr 1981	60,000
Glamis, Dunes, Ford Dry Lake (BLM)	June 1981	30,000
Beckwourth, etc. (USFS)	Apr 1983	25,000
Knoxville (BLM)	Apr 1984	25,000
Randsburg, Bodie, Saline Valley (BLM)	Apr 1984	25,000
Witter Springs, Cow Mountain (BLM)	Apr 1986	25,000
Lovelady Ridge, Little (USFS/BLM) Horse Mountain, etc.	Apr 1987	50,000
		416,000



* NOTE: NUMBER WITHOUT PARENTHESIS IS SITE IDENTIFICATION PER "LOCATION" COLUMN. THOSE WITH PARENTHESIS ARE QUANTITY REQUIRED

Figure 2-14. Near Term Requirements Federal Leasing Program

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a significant geothermal energy option in California. Figure 2-15 shows the land leasing requirements by calendar year associated with the scenarios. It represents a substantial increase in leasing activity. It can be realized providing:

(1) The leasing of geothermal lands in California receives a much higher priority within the BLM and USFS

(2) The budgets and staffs' of the responsible agencies are increased

(3) Leasing priorities are based on resource potential (re: the scenarios)

(4) Compliances with other requirements (re: National Forest Management Act and the Wilderness Act) are not allowed to delay leasing activities.

Therefore, it is recommended that there be a high level commitment by the federal government to leasing in California and that the appropriate increases in budget and staff increases by provided beginning in FY-78. Further it is recommended that the leasing schedules of Table 2-6, after industry review, be adopted by the federal government and that leasing progress be evaluated periodically against the established schedule. Finally, it is appropriate that the leasing process be examined to see if it can be "streamlined" to reduce the work load on the responsible agencies.

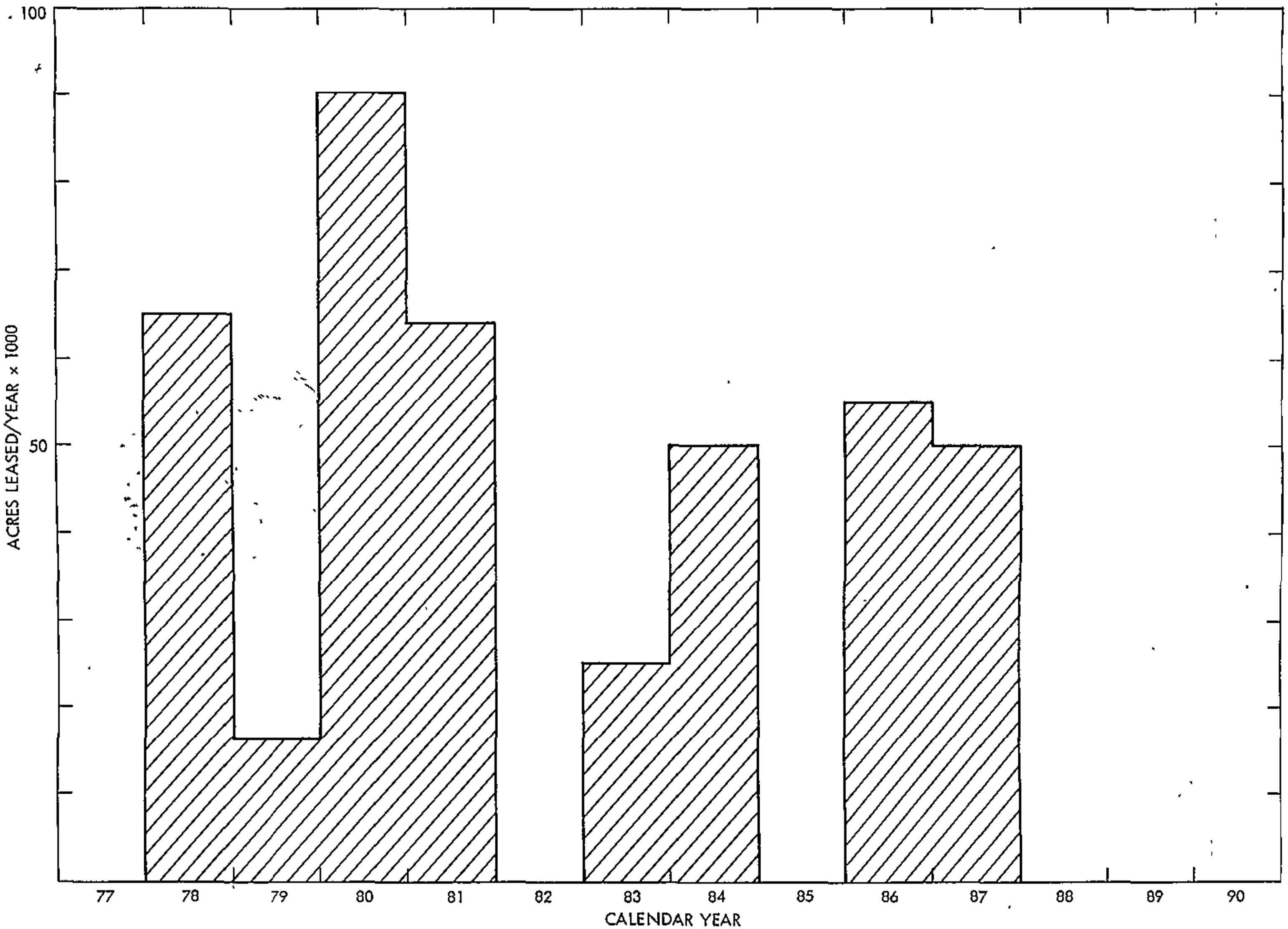

Figure 2-15. Federal Leasing Program Acreage Requirements

SECTION III

SUBREGION DEVELOPMENT REQUIREMENTS

If geothermal development is to occur in the time period assumed in the scenarios then not only do those common issues discussed in Section II need to be resolved but also many site and subregion specific issues. This section of the report addresses these site and subregion issues. First a development overview of each subregion is presented. This is followed by a discussion of the assumptions, rationale and development requirements associated with each scenario. Finally, the key issues in each subregion are summarized and recommendations are made to facilitate geothermal development. The specifics for the Geysers, the Imperial Valley, the Eastern Sierra and the Northeast subregion are presented in Sections III A, B, C and D respectively. The development of the Central Coast subregion is included in Additional Prospects, Section III E.

A. GEYSERS SUBREGION

The Geysers Subregion has the estimated potential of contributing over 2000 MW_e of electrical generating capacity to the states energy needs by 1985, 2650 MW_e by 1990 and over 3600 MW_e by the year 2000. Through 1985 most of the contribution will be from the steam resources. Post 1985 growth will be dependent on the development of the potentially large hot-water resources. Two separate scenarios have been prepared for the subregion; the first for the development of the steam field, the second for the hot water resources.

1. Geysers Subregion Overview

The subregion includes The Geysers Calistoga, Lovelady Ridge, Knoxville, Little Horse Mountain and Witter Springs KGRAs and is located in portions of Colusa, Lake, Mendocino, Napa, Sonoma and Yolo counties about 120 kilometers north of San Francisco. The five KGRA's consist of about 420,000 acres with close to 380,000 in the Geyser-Colistoga KGRA. Over 300,000 acres are state and private lands. Of the 40,000 acres associated with the four smaller, outlying KGRA's approximately 22,000 acres are under BLM and USFS jurisdiction. There are considerable more federal lands outside the KGRA's under non-competitive lease application. It is estimated that there are over 100,000 acres of land currently under lease in the subregion (Reference 12).

The main Geysers field, in the Geysers-Calistoga KGRA, is a relatively unique dry steam resource with an estimated potential which could exceed 2000 MW_e. Commercially, it is very competitive right now with other sources of energy. This is reflected in the high industrial interest and development of the field. Resource development has been underway for over 15 years. Over 200 geothermal wells have been drilled. When the Pacific Gas and Electric Company's unit 11 came on line in 1974 it raised the installed electrical capacity to 502 MW_e making it the largest geothermal installation in the world. The company has

plans to add another 1396 MW_e of capacity by 1985. The California Department of Water Resources and the Northern California Power Agency are also interested in obtaining electric power from the Geyers region. There are strong indications that significant hot-water resources also are present in the subregion. A well at Sulphur Bank Mine produced hot water at a temperature of 186°C at 1,520 meters (Reference 13). The USGS lists numerous hot springs in the greater Geysers area. However, the extent of the hot water resources has yet to be proven by deep drilling.

In recent years development at the Geysers has slowed. Unit 12, the first addition to be sought after the provisions of CEQA had gone into effect suffered considerable delays while the procedures and data requirements for the issuance of the necessary permits were being defined and the problems associated with hydrogen sulfide (H_2S) abatement were being resolved. In 1976 the development process was resumed and authority was granted to PG & E for units 12, 13, 14 and 15. The last of these units approved, unit 14, is expected to be on line in 1979.

H_2S abatement has been a serious problem holding up the further expansion of The Geysers. An iron catalyst system is currently installed on unit 11. PG & E has initiated a retrofit program on the remainder of units 1-12. New processes will be installed on succeeding units. Under the Northern Sonoma County Air Pollution Control Districts (APCD) rule 56.1 enacted in 1976 (Reference 14), H_2S emissions in the current Geysers field, which currently are 1670 lbs/h, must be reduced to 1350 lbs/h by December 31, 1976 and to 850 lbs/h by December 31, 1978. Emission standards after 1979 will be determined by the district by December 31, 1978, based on a review of air quality, emissions and meteorological data available at that time. It is important to the expansion of the steam field and the hot water fields that these abatement programs be successful.

PG & E expansion plans originally were based on Units 16 and 17 to be on line by 1980. However, because of the delays associated with the approval of Units 12-15 and the current H_2S abatement problems they have slipped their schedule to 1981. The maintenance of the new schedule requires that applications for approval of Units 16 and 17 be filed in 1977 and that approval be granted early in 1979 (assuming successful resolution of the abatement problem). The geothermal resources for these two units have been proven.

The geothermal exploration for the further expansion of the steam field has concentrated on the Cobb Mountain area closest to the existing Geysers field in Lake County and in Sonoma County south of the current field. Most of the lands associated with the main Geyser field have been leased. There are, however, approximately 5000 acres of federal "homestead" lands in this area to which the BLM has given high leasing priority. Because of the lack of resource assessment data there is uncertainty as to the need date of the leasing of the federal lands in the four outlying KGRAs. To have to lease all the federal lands in these KGRA's on a short schedule is a real concern to the BLM and USFS for as many as 10 separate EIS's could be required to lease the federal lands; more than their staff could handle (Reference 15).

There is a real possibility that all development activities on the further expansion at the Geysers could come to a complete halt. In recent years environmental concerns and land use conflicts have slowed the extension of the Geysers field into Lake County, a prime recreational area. Many of the residents and local regulatory agencies feel that the technology employed at the Geysers has been destructive of air quality, water quality, wild life habitat, and the landscape. A key issue in the subregion is the abatement of H_2S. Persons living downwind of the existing power plants complain of the "rotten eggs" aroma of H_2S and the noise of well testing. Another key issue is local control over development out of fear that:

(1) In the absence of a land use plan, economics will rule geothermal development with no consideration for the quality of life and no protection for sensitive ecological areas.

(2) Local viewpoints and inputs are not being heard or considered throughout the governmental review and approval process.

(3) Environmental laws are being ignored or are not being properly implemented.

(4) Potential non-electric applications in their area will be ignored.

In the spring of 1976 residents in the area formed the Lake County Energy Council, dedicated to the "intelligent development of energy resources in the county" (Reference 16). Membership now numbers more than 1,400 persons. During the summer of 1976 the Council instituted a lawsuit against proposed expansion on Mt. Knocti. Many people in the area would favor delaying geothermal development until environmental concerns are resolvable.

The Department of Fish and Game has similar concerns relative to the protection of wild life habitat and extensive fisheries in the area. The residents in the area, as represented by the Lake County Energy Council are disposed to go to court, as they have demonstrated, to obtain "controlled, intelligent" development.

The local agencies in general are hampered by an inadequate environmental base to support the timely analysis of proposed geothermal developments. To compound the problem these agencies are further hampered by both limited manpower and fiscal resources. A case in point is the current lack of adequate baseline meteorological data, ambient H_2S atmospheric data and reliable evaluation models for the local air pollution control district to monitor air quality and make projections necessary to assure that air quality standards will not be adversely affected by proposed developments. Four counties in the subregion (Lake, Sonoma, Napa and Mendocino) have joined together and have initiated a Geothermal Resource Impact Projection Study (GRIPS) which will be the basis of reconciling geothermal development with other important land uses. CERCDC and DOE have provided funds and staff support for the initial phase of the GRIPS study which is currently under way. A part of the study is the development of needed environmental baseline

data. The completion of this study is critical to avoiding further development delays in the subregion.

2. Geysers Scenario Definition and Rationale

a. The Geyser Steam Field. Figure 3-1 shows the near term requirements schedule associated with developing the steam field to its estimated 2000 MW_e capacity by 1986.* The power on-line increments are based on the current PG & E plans. They do not include the anticipated Northern California Power Association (NCPA) plants which may compete with the PG & E additions. Critical assumptions for the scenario include:

(1) Successful demonstrations of H_2S abatement technology.

(2) Support of the local APCD in monitoring air quality and developing air emission standards.

(3) Support of GRIPS which will provide the environmental data necessary to assess and permit geothermal development.

Other actions to facilitate development include the leasing of the remaining federal lands associated with the steam field including the 5000 acres of homestead lands where the Court of Appeals ruled the geothermal rights were still vested in the government. The scenario assumes that the resource for units 16 and 17 has been demonstrated and that EIS's or EIR's will be required for exploratory drilling for units 18 through 25. The lands in the steam field are a patchwork of federal, state and private lands. It was assumed, therefore, that the remaining development (in units 16-25) would be split evenly between federal and regional (state and local) agencies. This split is reflected in the environmental review and well permitting processes. It will be noted from the schedule (See Figure 3-1) that application for units 16 and 17 were submitted in 1977 and given exemption. Approval continues at the rate of two a year through 1980.

b. The Geysers Hot-Water Resources. Figure 3-2 shows the near term scenario requirements schedule for the development of the Geysers hot-water resources. Table 3-1 is an indexing of the various units and sites for the assumed scenario. Because of the high development interest in the steam field and the proximity to transmission lines development could move rapidly. The first plant is assumed to be on-line in 1983 and, beginning in 1985 expand up to 2000 MW at a rate of 100 MW_e per year. (This rate could prove to be low.) The assumed resource temperature is 200°C. It should be noted that while the geothermal potential of the hot-water resources is estimated to be large, very little is actually known of either the extent or temperature of the resource.

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*A discussion of the model in which the development requirements are based is presented in Appendix B.

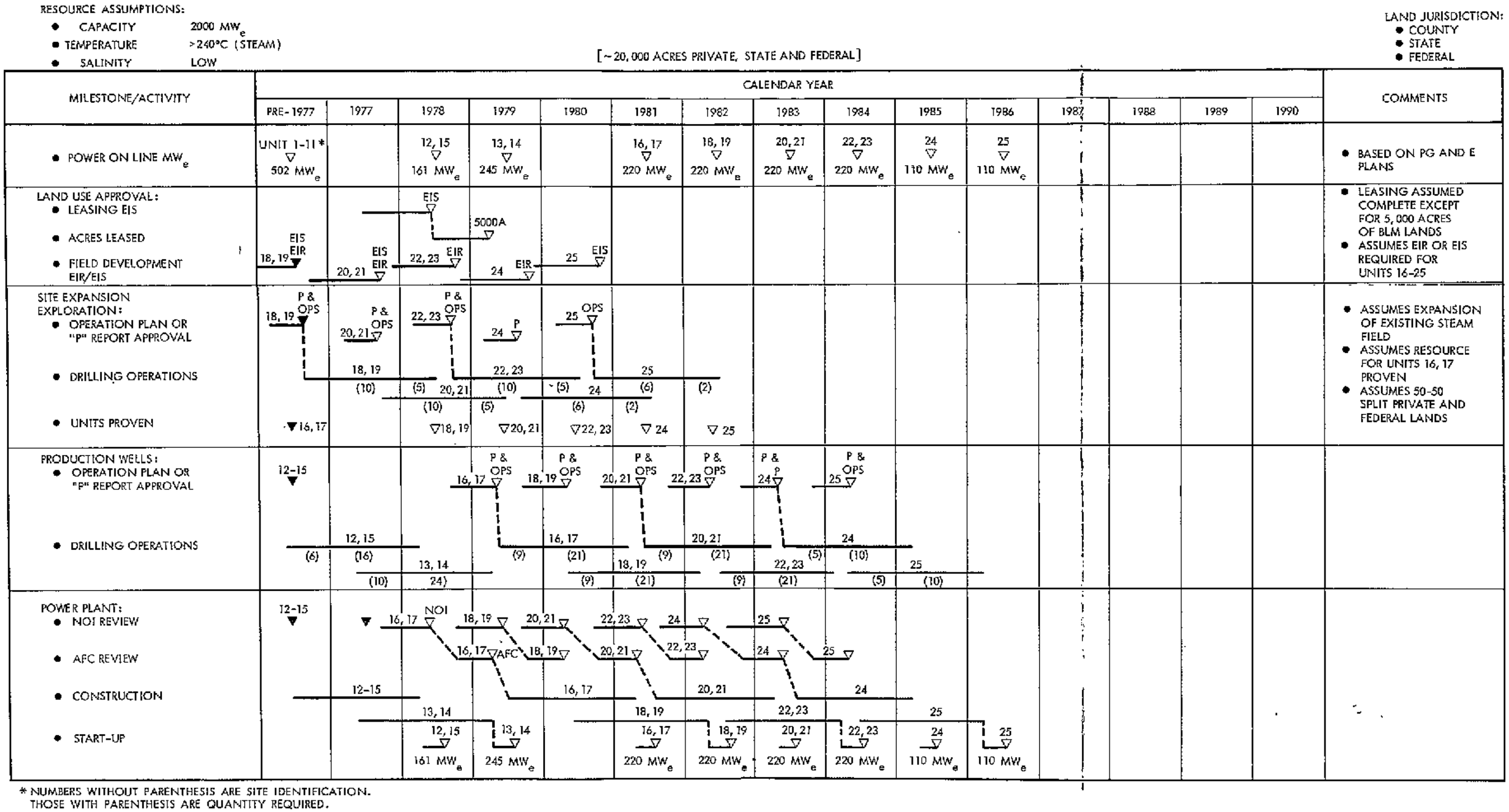
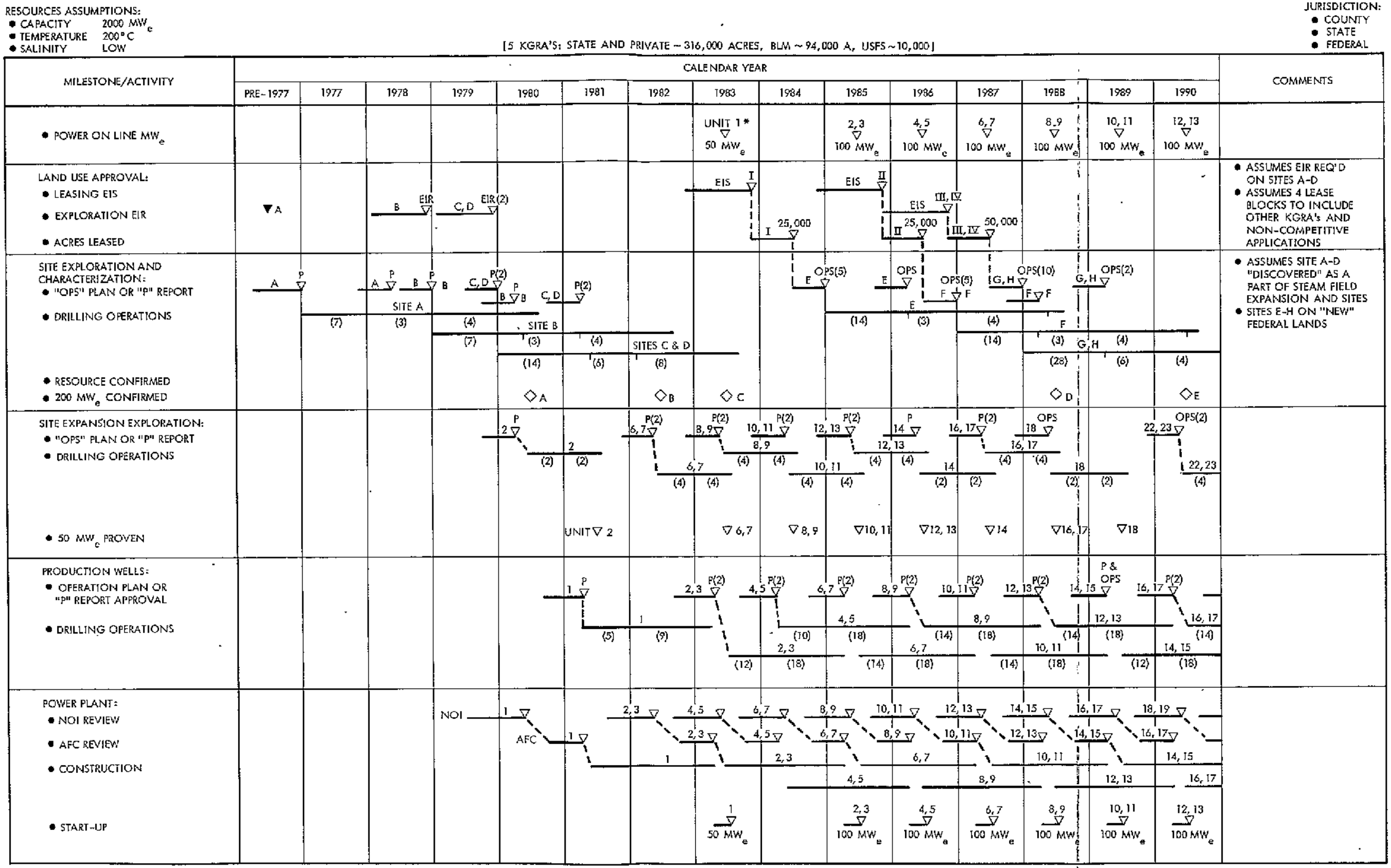


Figure 3-1. Scenario Near Term Requirements Schedule Geysers (Steam)



* NUMBERS WITHOUT PARENTHESIS ARE SITE IDENTIFICATION.
THOSE WITH PARENTHESIS ARE QUANTITY REQUIRED.

Figure 3-2. Scenario Near Term Requirements Schedule Geysers (Hot Water)

Table 3-1. 200 MW_e Site Index Geysers "Hot-Water" Scenario

Site @200 MW_e Each	Unit Numbers 50 MW_e Each	Lease Block and Need Dates	Comments
A	1, 2, 6, 10	Existing Leases	Over 100,000 Acres Leased in Subregion Assume private and state land.
B	3, 7, 11, 14		
C	4, 8, 12, 16		
D	5, 9, 13, 17		
E	15, 18, 22, 26	I (1984) Knoxville, Indian Valley	Lease Dates Should Be Re-evaluated Based on Detailed Industry Inputs. Assumes federal land.
F	19, 23, 27, 30	II (1986) Whitter & Cow Mountain	
G	20, 24, 28, 32	III (1987) Lovelady Ridge	
H	21, 25, 29, 33	IV (1987) Little Horse Mountain	
I	31, 34, 36, 38	Additions to Other Sites	
J	35, 37, 39, 40		

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The estimated current cost of the resource, from Figure 2-4, ranges between 46 to 62 mills/kWh. At this level the resource is not competitive with other sources of energy.

The estimated cost of power from this resource is dominated by drilling costs which can exceed $800,000 per well for this area. This would account for 40 mills/kWh. Actions to be taken to reduce well costs by the end of 1981, the assumed technology cut off date for the first plant are:

(1) Provide intangible drilling cost write-off which would reduce the 40 mill well-related cost to roughly 33 mills/kWh.

(2) Provide 22% depletion allowance which would reduce the well-related costs to approximately 28 mills/kWh.

(3) Reduce field development cost by 10% by improved drill bits which would reduce well related costs to approximately 25 mills/kWh.

It may well prove to be the case that by 1983 when the plant goes on line the cost of power could still be on the order of 45 mills/kWh; higher than the alternate sources of energy. In this event the first plant may have to be a cost shared demonstration plant to meet the 1983 power on line date. Because of the higher temperature and different reservoir properties (i.e., volcanic versus sedimentary), such a demonstration plant would not be duplicating the proposed plant at Heber.*

By 1985 when the second and third plants would be added, it should be possible to reduce the costs to less than 33 mills/kWh by the other actions described in Section II. The well stimulations and utilization technology efforts could prove to be particularly effective.

Not much is known about the hot water-resources. Therefore, the scenario assumes that initial development could occur on the existing 100,000 acres already leased in the subregion and that federal leasing of the outlying KGRA's would not be required until 1984. (This point should be confirmed with industry.) More extensive resource assessment in the subregion would be beneficial to establishing leasing and development priorities. The scenarios also assumes the satisfactory resolution of the H_2S abatement problem and the completion of the proposed GRIPS effort.

3. Geysers Subregion Program Requirements

Figure 3-3 summarizes the programmatic requirements necessary to realize the scenarios in the Geysers subregion where "critical"

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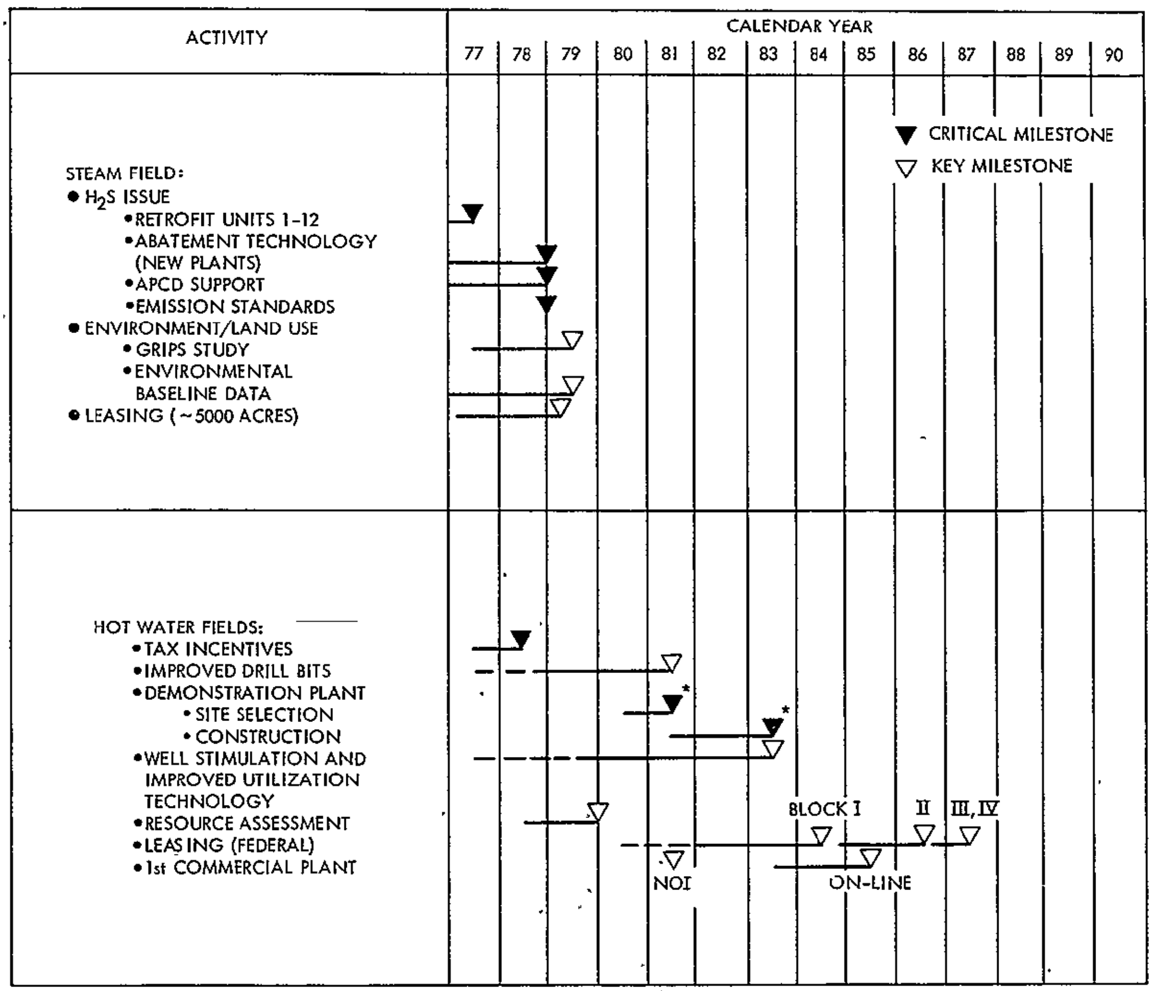
*A demonstration plant at Roosevelt Hot Springs or Valles Caldera by 1981 might replace the need for this Geysers demonstration.



*DEPENDENT ON MORE COMPLETE DATA

Figure 3-3. Geysers Subregion Program Requirements

milestones are those required for development to proceed. "Key" milestones are those probably required to facilitate accelerated development. The critical milestones include:

(1) Resolutions of H_2S issue by January 1979.

(2) Drilling tax incentives in 1978.

(3) Demonstration plant (tentative) by 1983.

Table 3-2 summarizes the near term development and regulatory activities associated with the two scenarios. It reflects the need for a marked increase in development activities over the next few years. Figure 3-4 shows projections of the effect of successful efforts to reduce H_2S emissions in the subregions.

B. THE IMPERIAL SUBREGION

This subregion contains seven KGRAs; Brawley, Dunes, East Mesa, Ford Dry Lake, Glamis, Heber and Salton Sea. All are in Imperial County except Ford Dry Lake which is in the southwest corner of Riverside County. The geothermal resources of the Imperial subregion have the potential of beginning to contribute significantly to the states energy needs by the mid 1980's. According to the scenarios, just under 500 MW_e of geothermal capacity could be on-line by 1985, 1900 MW_e by 1990, and 4100 MW_e by the year 2000. These estimates are based on four scenarios: Heber, East Mesa, Salton Sea; and Brawley. Not included are the prospects at the Dunes, Glamis and Ford Dry Lakes which are included in Section III E, "Additional Prospects".

1. Imperial Subregion Overview

Geothermal development activity is high in the Imperial Valley. The University of California at Riverside has conducted an active exploration program in the region since the early 1960s. Close to 70 wells have been drilled. As a result considerable data is available on the resource potential at Heber, Brawley, East Mesa and the Salton Sea KGRA's. These four KGRA's consists of over 220,000 acres of which 170,000 acres are private or state lands. The federal lands are located at East Mesa and the Salton Sea. It is estimated that over 140,000 acres currently are under lease by industry in the area including 12,000 acres of federal land at East Mesa.

Resource development at Heber is further advanced than any other hot-water resource in the state. Over 16 wells have been drilled and the resource has been estimated to be sufficient to support at least 800-900 MW_e of electrical capacity for 30 years. The resource temperature is 190^oC and of low salinity (i.e., <14,000 ppm). Four exploration companies are active in the Heber area: Chevron Oil, New Albion Resource Company (NARCO,) Magma Power and Union Oil. Development of the resource dates back to August of 1973 when NARCO, Magma and Chevron Oil agreed to join in a test program to evaluate the potential for commercial development

Table 3-2. Scenario Near Term Development Activities — The Geysers Subregion

Milestone/Activity	Pre 1977	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
							Calendar Year								
1. Environmental Approval															
• EIS's Initiated		2		1			1		1	2					
• EIR's Initiated		1	2	2											
2. Federal Acres leased	≈9,000			5,000					25,000		25,000	50,000			
3. Drilling Plan Review															
• Operation Plans		1	2	2	2	1		1				1	1	2	4
• "P" Reports		2	3	6	4	3	5	4	4	3	4	2	1	2	
4. Wells Drilled:															
• Exploration & Characterization		17	18	26	25	20	14	8	8	22	9	24	37	12	8
• Production	—	26	24	9	30	35	39	38	43	42	32	32	32	50	32
• Total	30	43	42	35	55	55	53	46	51	64	41	56	69	42	40
5. Utility Commencement (NOI Filing) - Unit		2	2	3	2	3	3	2	2	2	2	2	2	2	2
6. NOI/AFC Approval (Construction Initiated)				2	2	3	2	3	3	2	2	2	2	2	2
7. Power On-Line															
• Units Added	11		2	2		2	2	3	2	3	3	2	2	2	2
• MW_e Added			161	245		220	220	270	220	210	210	100	100	100	100
• MW_e Cumulative	502		663	908		1128	1348	1618	1838	2048	2258	2358	2458	2558	2658

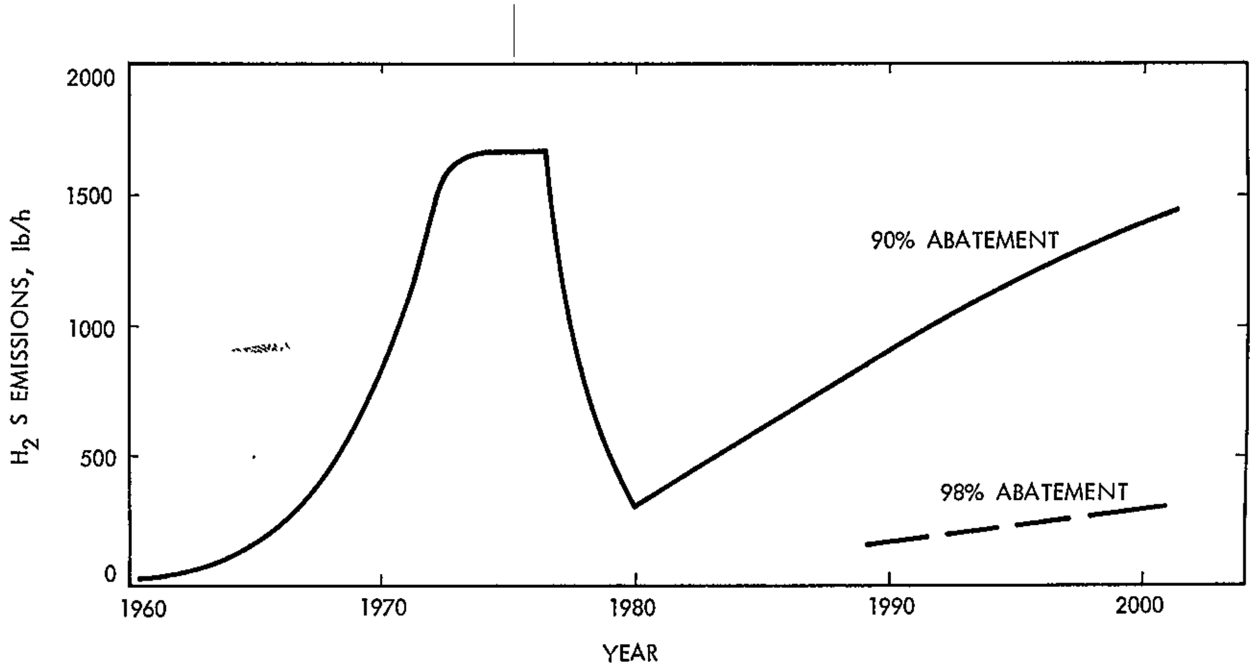


Figure 3-4. Estimate of H_2S Power Plant Emission (See Reference 15)

of the Heber field. Because of the lower temperature of the reservoir (compared with Niland) the geothermal fluid must be pumped to the surface to maintain a sufficiently high flow rate and well-head temperatures for efficient conversion. In 1974 installation of deep well pumps was completed and pumping and reinjection operations were initiated by Chevron. Heat exchanger tests, supported by EPRI, were conducted in conjunction with the operation of the well pumps. The results of the tests, completed in December of 1974, were favorable and indicated that heat exchangers could be designed for operation over fairly long periods without excessive scale build-up. Chevron has continued their resource assessment activities at Heber in cooperation with NARCO and the Union Oil Company. In 1975 EPRI initiated a series of studies leading to a proposed 50 MW_e geothermal demonstration plant at Heber based on the binary cycle. SDG&E would like to proceed with the construction and operation of such a plant at Heber which could go into operation in 1981.

The resource at East Mesa is similar to that at Heber with a temperature of 180-190°C and low salinity. The BUR has constructed a test facility at their site in the KGRA to evaluate the feasibility of desalinating of the geothermal brines. DOE, in cooperation with the BUR, has established a Geothermal Component Test Facility (GCTF) at East Mesa which is available to industry. Republic Geothermal and Magma Power have active resource development programs on their leases at East Mesa; Republic to the north of the BUR site and Magma to the south. Magma, in cooperation with NARCO, is proceeding with the development of a 10 MW_e pilot plant using their Magmamax process. The pilot plant is scheduled to begin operation in 1978. Republic has been granted a federal loan guarantee for field development leading to a commercial power plant in the early 1980's.

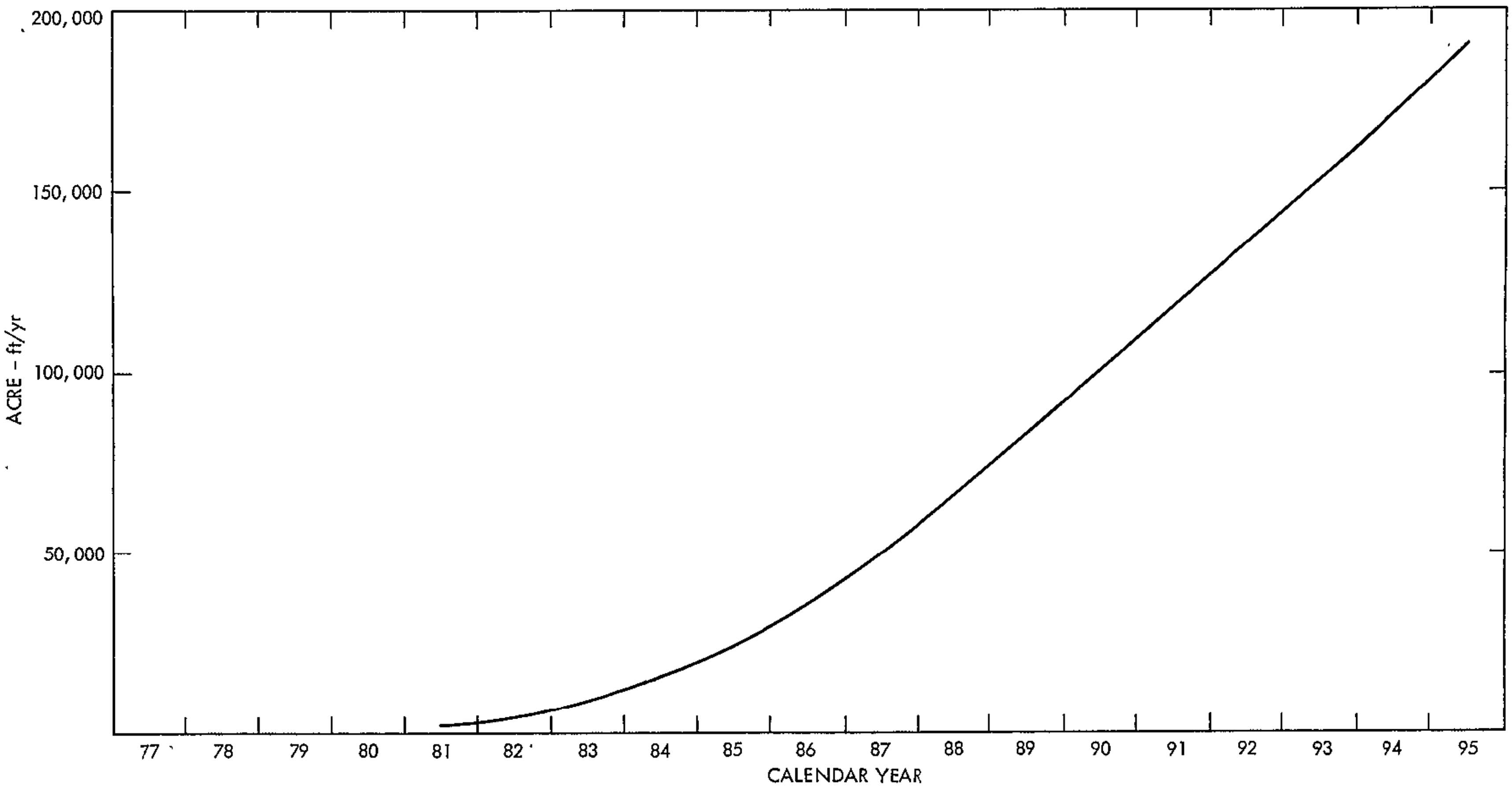
The resource at the Salton Sea KGRA is potentially very large and hot (i.e., >250°C). However, because of the high salinity (220,000 ppm) utilization is paced by the development of suitable conversion processes, reservoir and well completion technology. Work on this technology dates back to 1973 at which time a small scale test facility was constructed at the Niland site in the KGRA. The facility used a binary system in which flashed steam and brine from a separator were passed through heat exchangers which would heat an isobutane working fluid. The performance in both the steam and brine heat exchangers fell outside of design limits after 100 hours of operation due to excessive scaling. A redesign effort was initiated to improve the separation of the steam from the geothermal brine and to scrub the steam to remove entrained solids. In mid-1974 the new steam separation system was tested with very promising results. In July of 1975, DOE and SDG&E entered into a joint project agreement for the construction and operation of a Geothermal Loop Experimental Facility (GLEF) using a multiple flash binary cycle based on the redesigned steam separators. The GLEF will determine whether the highly saline brine can be extracted over long periods of time at sufficiently high temperature and whether the special heat exchanger equipment necessary to generate power from the highly saline geothermal resource will perform reliably. Construction of the GLEF was completed in April of 1976 and the plant went into operation in early May. Operations to date have been successful. In 1979 DOE is

planning to add a 10 MW_e hydrocarbon turbine to the current test loop. DOE is considering the establishment of a well completion and extraction technology test facility at another site in the Salton Sea KGRA in cooperation with a consortium consisting of the Union Oil Co., Southern Pacific Land Company and the Southern California Edison Co. The effort is directed at developing and demonstrating the technology that will increase well life and will sustain high flow rates. Republic Geothermal has been very active in the Westmoreland where they have drilled 6 wells.

At Brawley the Union Oil Company has drilled 6 wells. The resource is similar to that at the Salton Sea with a temperature greater than 250°C but of lower salinity (i.e., <90,000 ppm). The development of the resource will benefit from the technology developed in the Salton Sea KGRA but because of the lower salinity could probably proceed with commercial development sooner.

Unlike the situation at the Geysers the attitudes of those in the subregion are predominantly pro-geothermal development providing there are local controls. Imperial County has received a grant from the National Science Foundation (NSF) to develop a geothermal element for the County General Plan. Under this grant, the county is evaluating land-use plans, socio-economic impacts of geothermal development, probable environmental impacts and other related factors prior to any actual development. A great deal of information on the resource in Imperial County, and on the probable impacts of its development, has been generated in the past and continues to be generated. A three-year, six-million-dollar background study of the county is now being conducted by the Lawrence Livermore Laboratory under DOE funding. Numerous other studies of a more specific nature are being conducted under public and private funds. As a result of these activities, and present favorable county attitudes, geothermal development in Imperial County, when it comes, is unlikely to face much local opposition. However, Imperial County is vitally concerned that the state or the federal government will ignore their county's desire for local control over developments in their area. Agreements between the responsible federal, state and county agencies need to be made to assure harmonious development.

A key issue that potentially could limit development is cooling water availability. Figure 3-5 shows the near term cooling water requirements. The county will require that all geothermal fluids be reinjected to guard against subsidence which could affect the Valley's complex agricultural water drainage system. This means that cooling water must be made available from sources other than geothermal fluids. Cooling water availability has been cited as a major concern, although this concern is not universally shared by all investigators. The major source of water for the Imperial Valley is the Colorado River. The prime use of water is irrigation of the major agricultural developments of the area. Increasing the amount of water withdrawn from the Colorado, or diverting water from agricultural use do not appear to be acceptable solutions. Withdrawing agricultural runoff water from the drainage system feeding the Salton Sea is the most commonly considered solution. Other possible solutions include the introduction of new cooling water sources or the development of new cooling technology.



*BASED ON 70 ACRE FEET PER MW/YR AND 0.75 AVAILABILITY FACTOR

Figure 3-5. Imperial Subregion Near Term Cooling Water Requirements

Land-use conflicts were also a potential concern in Imperial Valley, since any substantial withdrawal of land from agriculture to meet the needs of geothermal development will probably be opposed. However, UC Riverside studies show that the potential conflict can be minimized by proper siting of drilling islands and power plants, and the routing of piping and transmission lines alongside existing roads. By such measures, withdrawal of land from agriculture can be kept within 1 to 2%.

2. Imperial Scenario Definition and Rationale

a. Heber. Figure 3-6 shows the near term scenario requirements schedule for geothermal development at Heber. Table 3-3 is an index of the respective units and 200 MW_e sites assumed. Resource characterization work has been completed and the first commercial scale unit can be on line in 1981.* As explained in Section II B, this first plant, Unit 1, will have to be a cost shared demonstration plant as the current estimated cost of power from this resource, from Figure 2-4, ranges from 40 to 56 mills/kWh. The first commercial unit is assumed to be completed in 1984. The NOI for this unit would have to be filed in mid 1980, well into the demonstration plant construction cycle. Construction on unit 2, however, would not begin until the demonstration plant (unit 1) had been in operation for a year. Hence, its design would benefit from the knowledge gained in Unit 1.

The rapid development of the resource at Heber is dependent on a successful demonstration of the economics of geothermal power generation using binary technology and steps to reduce the cost of power. The granting of the intangible drilling cost write off and application allowance would reduce the estimated cost of power to 34 to 46 mills/kWh (compared with 40 to 56 mills/kWh). Further reductions are possible by the development of improved down-well pumps which could increase the flow rate of each well and improved heat exchanger technology which could raise the efficiency of the plant. These actions coupled with accepting a lower rate of return on investment (15%) could reduce the estimated cost of power to between 25 and 34 mills/kWh and make its use competitive. The improved technology would have to be available in 1981 to be incorporated into the design of unit 2, the first commercial plant.

With the successful development of these first two units it was assumed that 500 MW_e of generating capacity could be on line by 1990 and the capacity increasingly at the rate of 100 MW_e per year. Because the resource is located on private lands, it is assumed that Imperial County would have lead responsibility for land use decisions on field development and would work cooperatively with the Energy Commission on plant siting.

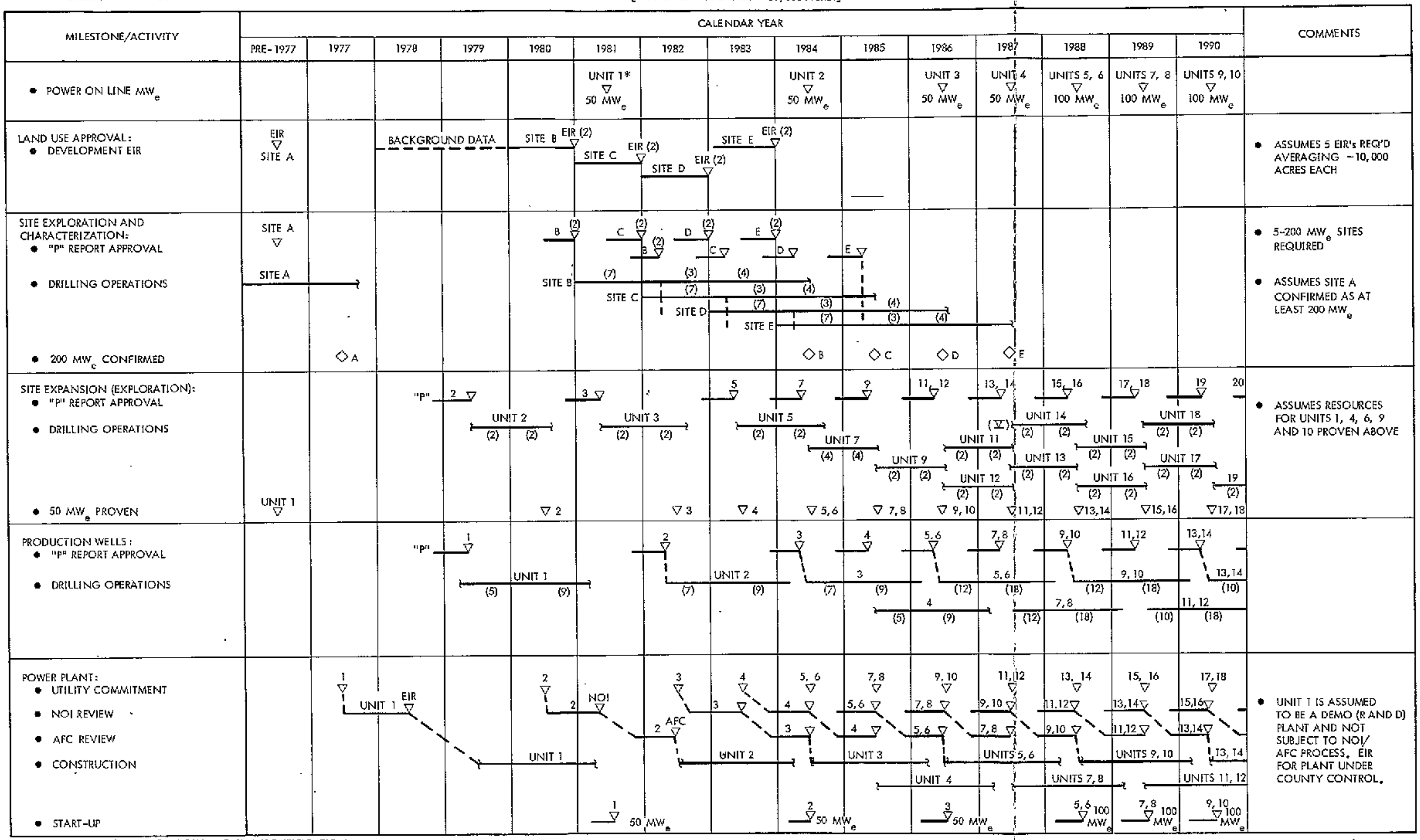
b. East Mesa. Figure 3-7 shows the scenario near term requirements schedule for East Mesa and Table 3-4 the site/unit index. The KGRA is primarily federal lands of which close to 12,000 acres have

*The current SDG&E scheduled is targeted for a 1980 start-up.

RESOURCE ASSUMPTIONS:
- CAPACITY 1000 MW_e
- TEMPERATURE ~190°C
- SALINITY LOW

[KGRA: PRIVATE LANDS ~59,000 ACRES]

LAND JURISDICTION: IMPERIAL COUNTY



* NUMBERS WITHOUT PARENTHESIS ARE SITE IDENTIFICATION. THOSE WITH PARENTHESIS ARE QUANTITY REQUIRED.

Figure 3-6. Scenario Near Term Requirements Schedule Heber

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RESOURCE ASSUMPTIONS:
- CAPACITY 500 MW_e
- TEMPERATURE ~180°C
- SALINITY LOW

[KGRA: FEDERAL ~33,000 ACRES, PRIVATE ~5,000 ACRES]

JURISDICTION: PRIMARILY FEDERAL

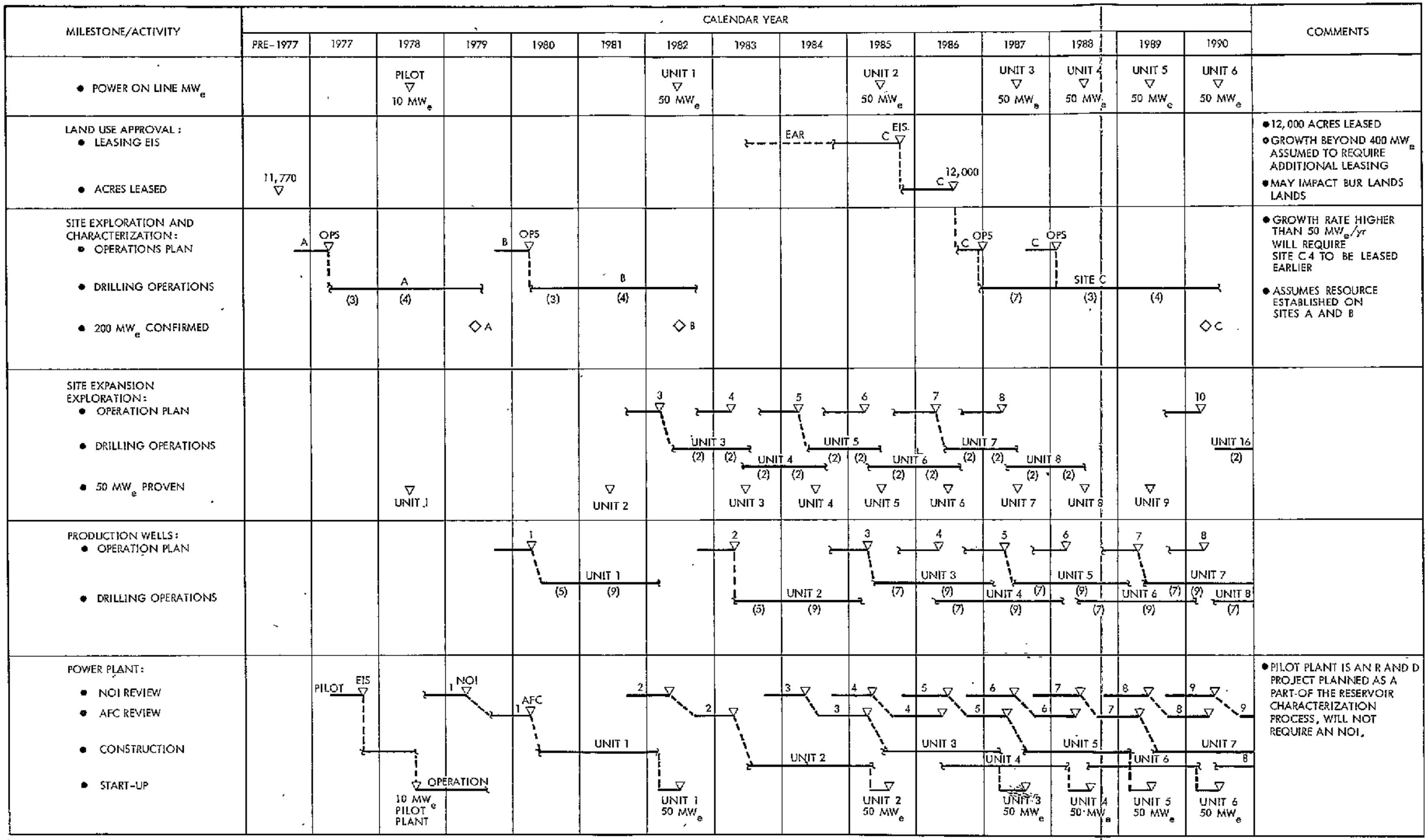


Figure 3-7. Scenario Near Term Requirements Schedule East Mesa

Table 3-3: 200 MW_e Site Index -- Heber Scenario

Site @ 200 MW_e Each	Unit Numbers 50 MW_e Each	Lease Block
A	1, 2, 3, 5	Existing Private Leases
B	4, 7, 11, 15	
C	6, 9, 13, 17	
D	8, 12, 16, 19	
E	10, 14, 18, 20	

been leased. While the scenario shows that additional lands would not be required until 1986 discussion with USGS personnel indicate that these lands may be required sooner to facilitate the expansion of development on the two existing lease blocks. For this reason the proposed leasing schedule, Section II D, shows a need date for the additional leases of July 1979. This will require the concurrence of the BUR.

The resource at East Mesa is similar in characteristics to that at Heber and as a result would benefit from the development activities at that site. The scenario reflects the current Magma activities to place a 10 MW_e pilot plant into operation by mid 1978. The plant is an R and D project as a part of the reservoir characterization process but should also be valuable in demonstrating binary cycle technology which would benefit development of the Heber demonstration project. The first commercial unit is shown to go into operation in 1982. However, there are large uncertainties on this date. If the Republic Geothermal loan-guaranteed resource development

Table 3-4: 200 MW_e Site Index
East Mesa Scenario

Site @ 200 MW_e Each	Unit Numbers 50 MW_e Each	Lease Block	Comments
A	1, 3, 5, 7	Existing Leases	Additional leasing of BUR land may be required in 1979 to support development on existing leases rather than in 1986 as shown.
B	2, 4, 6, 8		
C	9,10	(1986)	

activities are successful and low well costs and high flow rates are achieved, then it may be possible to place a flashed steam power plant into operation in 1980. If not and flow rate is the limiting factor, then it may be possible to employ the stepped-well technology proposed by Elliot (Reference 17) as a means of eliminating "throttling" in the well and improve flow rates substantially. This technology would have to be demonstrated by late 1979 in order to support a flashed steam plant in 1982. If it is demonstrated that flashed steam technology is not appropriate the first commercial plant could slip to 1984 consistent with the availability of binary technology from Heber. The subsequent rate of expansion could be faster than indicated based on the agressiveness of the current development activities at East Mesa demonstrated by both Magma and Republic.

The lands associated with East Mesa are managed by the federal government. Development, therefore, will require close cooperation between federal, state, and local agencies.

c. The Salton Sea. Figure 3-8 gives the near term requirements schedule for the Salton Sea scenario. Table 3-5 is its corresponding site/unit index. The resource is hot (>250°C) but also very highly saline (220,000 ppm). This high saline brine causes heat exchangers to foul, well casings to fail and reservoirs to plug. The development and demonstration of the technology to solve these problems is critical to commercial utilization of this large resource which has been estimated to exceed 2000 MW_e potential. The current DOE GLEF facility has focused on the development of the utilization technology but has also built some confidence in sustained flow from the wells. There are plans to add a binary turbine to the loop for pilot operations by mid 1979. To date operations have been very successful. The critical remaining element is well completion and extraction technology. DOE has tentative plans to locate a facility for developing this technology in the KGRA in 1978. The proven technology from such a facility would have to be available by 1980 in order to support the decision to construct the first commercial plant by 1982. This is a very tight schedule considering the magnitude of the problems.

The current cost of power from the Salton Sea resources is estimated to range between 33 and 45 mills/kWh. The granting of the tax incentives should reduce the cost to from 29 to 40 mills/kWh. If it can be shown that the expected cost of power is near the lower limit (i.e., 29 mills/kWh) then there is a good possibility that the 1982 date can be met. If not, then additional measures would be necessary. The key technical steps to further reduce cost include:

(1) Well stimulation to increase or maintain flow.

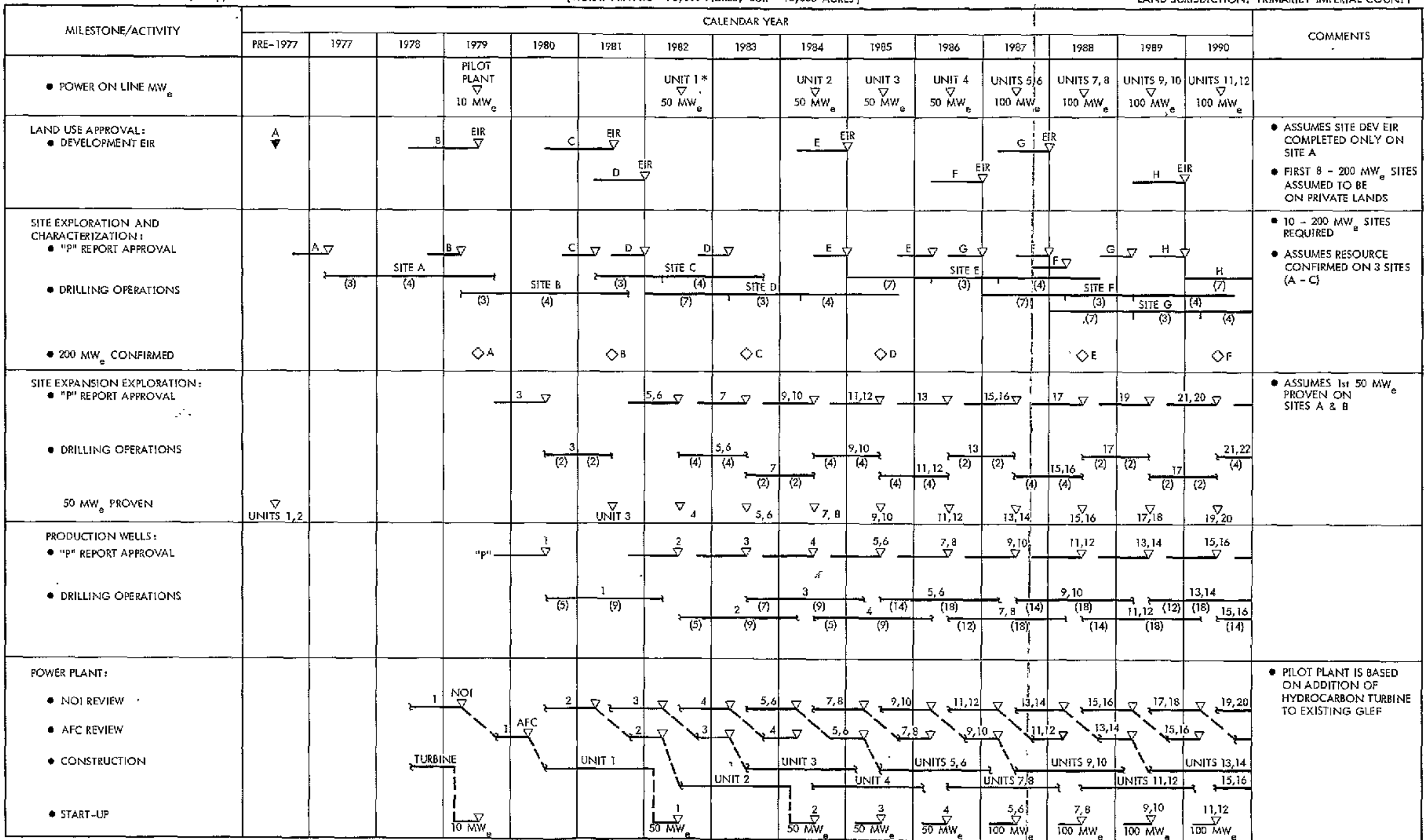
(2) Improved well completion technology to increase well life.

(3) Improved conversion technology to improve cycle efficiency.

RESOURCE ASSUMPTIONS:
- CAPACITY 2000 MW_e
- TEMPERATURE >300°C
- SALINITY >200,000 ppm

[KGRA: PRIVATE ~76,000 ACRES, BLM ~18,000 ACRES]

LAND JURISDICTION: PRIMARILY IMPERIAL COUNTY



* NUMBERS WITHOUT PARENTHESIS ARE SITE IDENTIFICATION. THOSE WITH PARENTHESIS ARE QUANTITY REQUIRED.

Figure 3-8. Scenario Near Term Requirements Schedule Salton Sea

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Table 3-5: 200 MW_e Site Index
Salton Sea Scenario

Site @ 200 MW_e Each	Unit Numbers 50 MW_e Each	Lease Block
A	1, 3, 5, 9	Existing Private Leases
B	2, 6, 10, 13	
C	4, 7, 11, 15	
D	8, 12, 16, 19	
E	14, 17, 21, 25	
F	18, 22, 26, 29	
G	20, 23, 27, 31	
H	24, 28, 32, 35	
I	30, 33, 36, 38	
J	34, 37, 39, 40	

With these additional technological advances, the tax incentives and a lower rate of return on investment the cost range should approach 22 to 30 mills per kWh where it would be very competitive with other sources of energy. If all these measures were required the first commercial plant could slip to 1985. However, the field could be expanded at a much higher rate than the 100 MW_e per year assumed.

d. Brawley. Figure 3-9 presents the near term requirements schedule for the Brawley scenario while Table 3-6 is the site index. The resource at Brawley is similar in its characteristics to that of the Salton Sea but not as saline (<90,000 ppm). It is assumed, therefore, that the resource development is more dependent on the technology developed and demonstrated at the Salton Sea rather than that at East Mesa or Heber. However, because the salinity problem is less severe than that at the Salton Sea there is more of a likelihood that the schedule for the first commercial plant on-line in 1983 can be met without the additional technological steps discussed in the previous scenario. It is assumed, therefore, that the first plant will use flashed-binary technology. While the NOI on this first plant would have to be filed by late 1979 before the well technology had been thoroughly demonstrated, the actual construction would not start until mid-1981. It is a tight but potentially feasible schedule.

According to the scenario 500 MW_e of geothermal capacity could be on line by 1990 and the full 1000 MW_e assumed potential by 1995. Because of the high resource temperature, the cost of power could be very attractive; in the range of 22 to 30 mills/kWh by 1985.

Table 3-6: 200 MW_e Site Index
Brawley Scenario

Site @ 200 MWe Each	Unit Numbers 50 MW_e Each	Lease Block	Comments
A	1, 2, 4, 7	Existing private leases	Assumed on existing private lands
B	3, 5, 9, 13		
C	6, 10, 14, 17		
D	8, 11, 15, 18		
E	12, 16, 19, 20		

3. Imperial Subregion Program Requirements

Figure 3-10 summarizes the key program requirements necessary to support the growth postulated in the scenarios. As with all the hot-water resources, both the intangible drilling cost and depletion allowance are critical because of their effectiveness in reducing the cost of geothermal power. The demonstration plant in 1981 is a critical need as was discussed in Section II B. It is not expected that the demonstration plant itself will be economically competitive. Therefore, improved downwell pumps, heat exchangers and turbines will probably be necessary to support the first commercial plant. The East Mesa requirements reflect the support potentially needed to get a commercial flashed steam plant on line in 1982. The flashed-binary cycle technology required for the highly saline resources at the Salton Sea and Brawley is being developed and demonstrated at the GLEF. Converting the facility to a 10 MW_e pilot plant will provide early design and operational experience with the hydrocarbon turbines required for the binary and flashed-binary cycles. As previously discussed, it is critical that well completion and extraction technology be developed for these corrosive brines. Finally, because the availability of cooling water has been identified as a factor which eventually could limit geothermal development in the Imperial Valley, it is recommended that further studies be initiated to examine alternative approaches to resolving this problem.

Table 3-7 summarizes the near term development and regulatory activities associated with the four scenarios.

C. THE EASTERN SIERRA SUBREGION

Five KGRAs are located in the Eastern Sierra subregion. Bodie, Coso Hot Springs, Mono-Long Valley, Randsburg, and Saline Valley. Bodie and Mono-Long Valley KGRAs are in Mono County, Coso Hot Springs and Saline Valley in Inyo County, and Randsburg KGRA in San Bernardino County.

RESOURCE ASSUMPTIONS:
- CAPACITY 1000 MW_c
- TEMPERATURE ~ 300 °C
- SALINITY <90,000 ppm

[KGRA: (PRIVATE ~29,000 ACRES)]

LAND JURISDICTION: IMPERIAL COUNTY

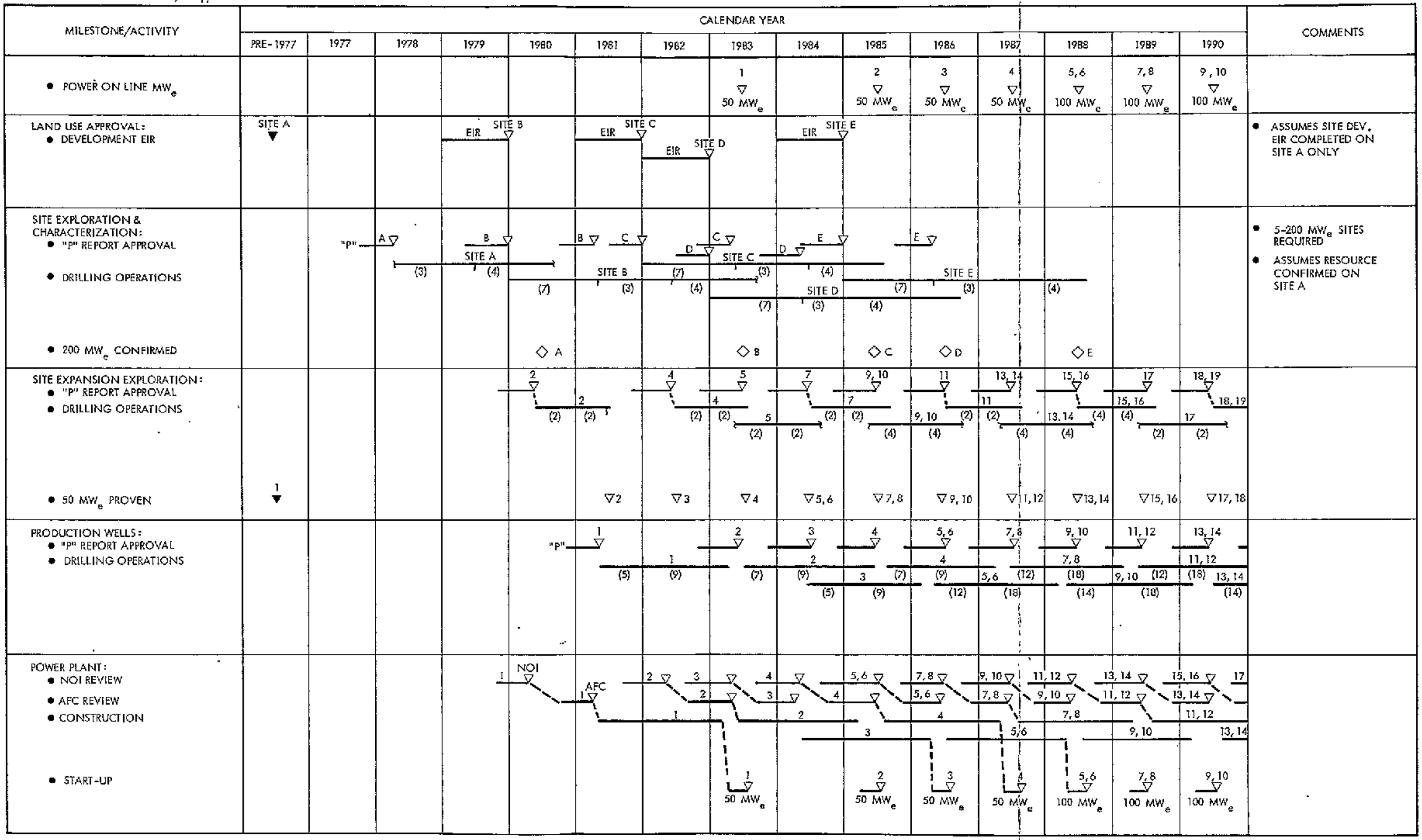

Figure 3-9. Scenario Near Term Requirements Schedule Brawley

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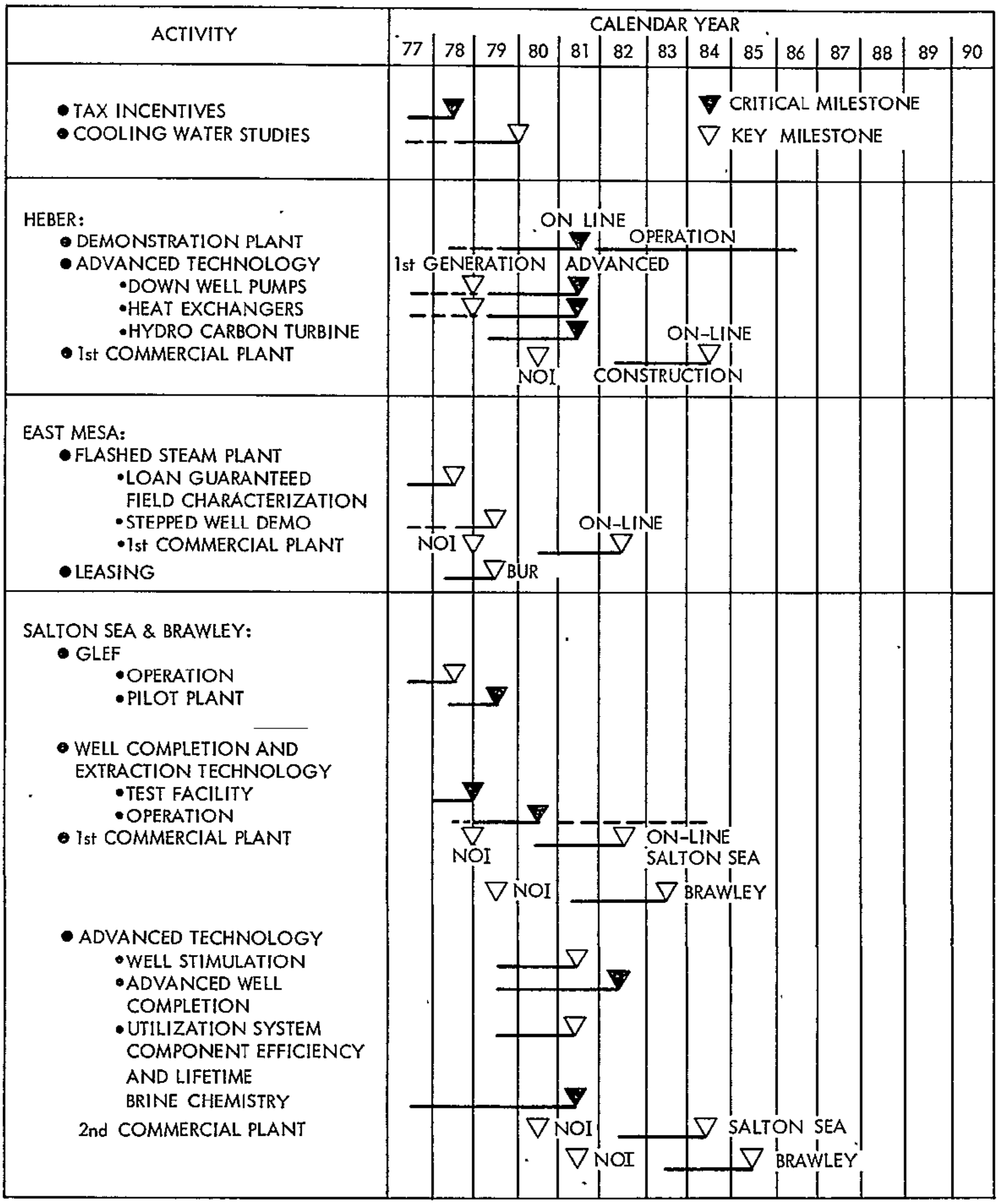


Figure 3-10. Imperial Subregion Program Requirements

Table 3-7. Scenario Near Term Development Activities -- Imperial Subregion

Milestone/Activity	Pre 1977	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Comments
	Calendar Year															
1. Environmental Approval																
• EIS's		1(P)*														
• EIR's		1(D)	1	1	3	4	3	2	2		1	1		1		
2. Federal Acres Leased	12,000			10,000												
3. Drilling Plan Review																
• Operation Plans		1		1		1	2	1	2	2	3	2	1	1		
• "P" Reports		2	3	4	6	11	11	11	12	12	13	13	11	12	0	
4. Wells Drilled:																
• Exploration & Characterization	16	6	11	9	20	23	41	43	45	49	32	39	36	27	24	
• Production				5	19	23	21	37	44	60	88	108	110	104	108	
• Total	16	6	11	14	39	46	62	80	99	109	120	147	146	131	132	
5. Utility Commitment (NOI Filing) - Units		1	2	1	2	3	3	5	7	7	7	7	7	7	7	
6. NOI/AFC Approval (Construction Initiated)			1(D)	2	1	2	3	3	5	7	7	7	7	7		Demo not subject to NOI process
7. Power On-Line																
• Units Added					1	2	1	2	3	3	5	7	7	7		
• MW_e Added		10(P)	10(P)		50	100	50	100	150	150	150	250	350	350		
• MW_e Cumulative		(10)	(20)		50	150	200	300	450	600	850	1200	1550	1900		

*P signifies pilot; D signifies demonstration.

Scenarios have been prepared for the Mono-Long Valley and Coso Hot Springs KGRA.* While the scenarios show that only 100 MW_e of geothermal capacity could be on line in 1985, they also indicate that the capacity could grow to 900 MW_e by 1990 and over 2000 MW_e by 1995. If these resources are as large as indicated by the USGS assessment (See Table 1-7), then the scenario projections could be low. Because of their promise, the confirmation of this potential by deep exploratory drilling in the next few years would establish that California, in fact, does have a significant geothermal option! Most of the lands in the subregion are under federal management. Hence, the federal leasing program paces development.

1. Eastern Sierra Subregion Overview

The Eastern Sierra subregion is unique in that although it potentially contains the largest resources in the state, over 10,000 MW_e for 30 years (See Reference 4) the existence of the resources generally has not been proven by deep drilling. The two major identified resources are at Long Valley and Coso Hot Springs. There has been extensive USGS geophysical and geological surveys in the Long Valley area. There also has been assessment work by the Navy at Coso where, currently, an exploratory well is being drilled.

The Mono-Long Valley KGRA is large; consisting of about 460,000 acres. Approximately 105,000 acres are under the control of the BLM and 290,000 acres by the USFS. Of the remaining 65,000 state and private lands, 55,000 acres of state lands are associated with Mono Lake. There are three distinct resource prospects: Mono Lake in the northern portion of the KGRA, the Mono Craters in the central portion, and Long Valley in the south. The Long Valley area consists of up to 100,000 acres and is the center of current development interests. Exploration activities date back to the 1959-1962 time-period when Magma Power drilled 10 shallow exploration wells near Casa Diablo Hot Springs. The wells reached a maximum depth of 323 meters and a temperature of 178°C (See Reference 13). In 1974 the BLM leased three blocks consisting of 5,500 acres in the Long Valley area. The blocks controlled by Chevron and Getty Oil are currently under litigation on "grandfather" rights and as a result, no development has occurred. A well drilled in the third block by Republic Geothermal in 1976 was not successful. Currently, an additional lease block comprised of 4000 acres of BLM lands and 26,000 acres of the USFS are under study in Long Valley. The necessary EIS is underway, however, its completion could be delayed as was discussed in Section II D.

SCE is interested in the development of the Long Valley resource to supplement their limited, local power generating capacity. DOE has funded a study which could lead to the heating of Mammoth Lakes Village by geothermal fluids. This region is a very popular recreation

*The other KGRA's are included in the "Additional Prospects" in Section III E.

area and, hence, is environmentally very sensitive. Private and local interests could induce significant delays or even denial of the leasing activity. In order to avoid unnecessary confrontations, the USFS and the BLM have initiated a strong public involvement program of potential geothermal developments.

Coso is a particularly promising resource which could be very large and hot. The KGRA is comprised of 52,000 areas: 8000 private and state, 17,000 BLM and 27,000 under the jurisdiction of the U. S. Navy. The BLM did have plans for a lease sale of their 17,000 acres in 1978. However, they have revised their plans and are currently working with the Navy on a plan for the leasing of both the BLM and Navy lands which would minimize this potential impact on naval test range operations and possibly give the Navy first call on the power generated in times of emergency. The Navy and the BLM currently are working on a schedule which could make the lands available for leasing in the spring of 1979. In the meantime the Navy is continuing with its resource confirmation program. There is a high industry interest in Coso.

2. Eastern Sierra Scenario Definition and Rationale

a. Mono-Long Valley. Figure 3-11 gives the near term requirements schedule for the Mono-Long Valley scenario. Table 3-8 is the site index. The resource temperature is estimated to be 220°C and the current cost of power range from 42 to 55 mills/kWh. If the additional Long Valley leases (Block II) are let in 1978 (and not held up by the USFS) then the first commercial power plant could be on line in 1985. The NOI for this plant would have to be filed in 1981 and construction could begin in 1983. Like the Geysers hot-water fields the power costs are dominated by the cost of the wells. Because the plant follows that at the Geysers (hot-water scenario) by two years, it would benefit from the actions proposed to support that development (See Figure 3-3). The key actions include:

(1) Tax incentives (1978).

(2) Improved drill bits (1981).

(3) Well-stimulation technology (1983).

(4) Improved utilization technology (1983).

(5) Demonstration plant (1983).

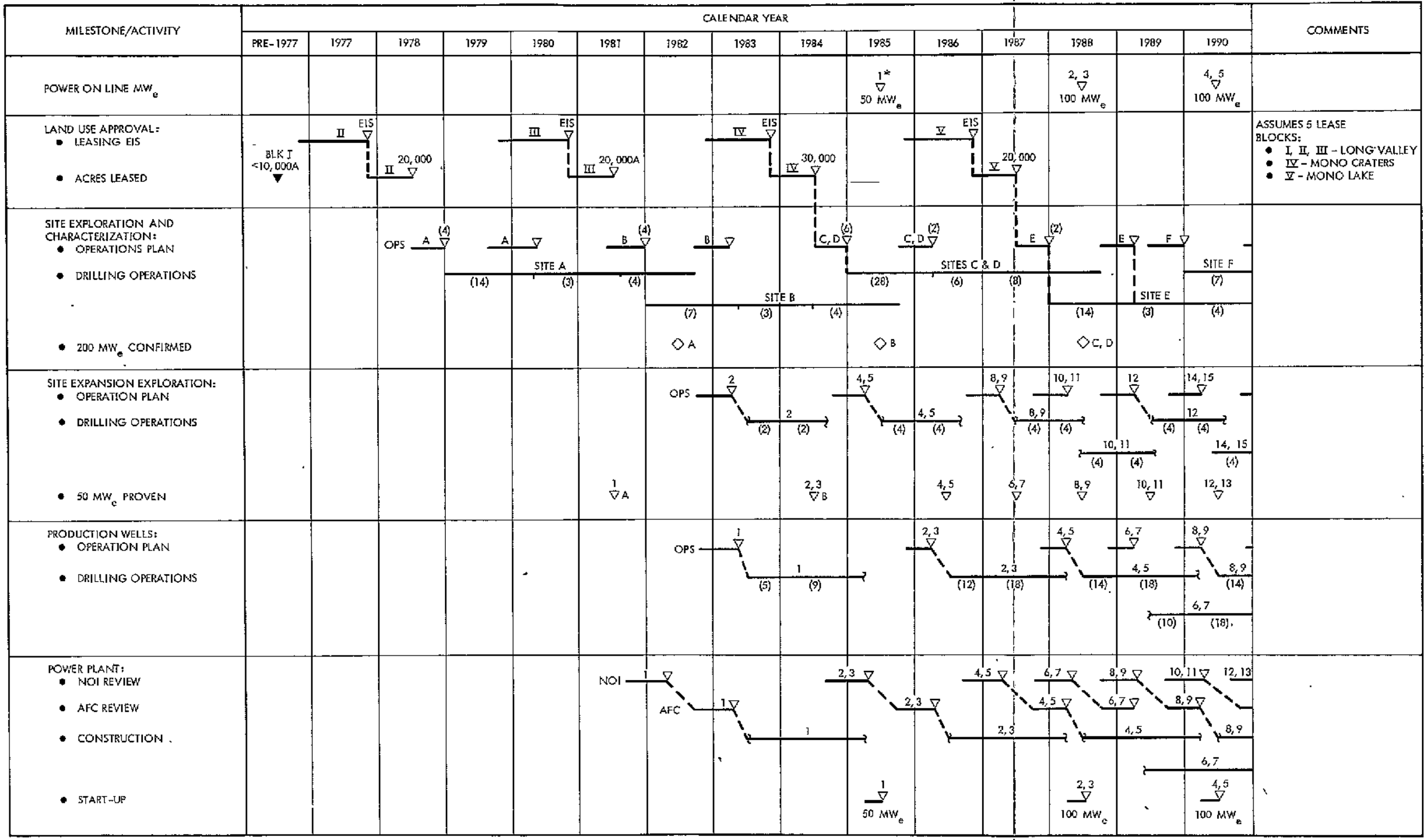
With these actions the estimated cost of the power could be in the range of 27 to 33 mills/kWh by 1985 excluding transmission costs. At these costs its utilization would be extremely attractive. However, because of the environmental sensitivity of the area, it is assumed that expansion would be slow until the public gained confidence that geothermal development could be environmentally acceptable. Two units are assumed in 1988 and by 1990 the rate of development could be 100 MWe per year.

RESOURCE ASSUMPTIONS:

- CAPACITY 2000 MW_e
- TEMPERATURE 220°C
- SALINITY LOW

[STATE AND PRIVATE LANDS ~63,000 ACRES, BLM ~104,000, USFS ~288,000]

JURISDICTION: PRIMARILY FEDERAL



*NUMBERS WITHOUT PARENTHESIS ARE SITE IDENTIFICATION. THOSE WITH PARENTHESIS ARE QUANITY REQUIRED.

Figure 3-11. Scenario Near Term Requirements Schedule Mono-Long Valley

A

Table 3-8: 200 MW_e Site Index Mono-Long Valley Scenario

Site @ 200 MW_e Each	Unit Numbers 50 MW_e Each	Lease Block	Comments
A	1, 2, 4, 8	II (1978) Long Valley "Grandfather" lands	Forest Service considering leasing III, IV and V as one block in 1981 rather than in suggested individual blocks
B	3, 5, 9, 12	I (already leased) and III (1981) Long Valley additions	
C	6, 10, 14, 18	IV (1984) Mono craters	
D	7, 11, 15, 19		
E	13, 16, 20, 24	V (1987) Mono Lake	
F	17, 21, 25, 28	Assumed additions to above blocks	
G	22, 26, 30, 34		
H	23, 27, 31, 35		
I	29, 32, 36, 38		
J	33, 37, 39, 40		

The critical requirement is maintaining lease block II schedule. The remaining leases are less critical. The USFS would probably let the remaining leases as one large block rather than as three blocks as indicated.

b. Coso Hot Springs. Figure 3-12 is the near term requirements schedule for the Coso scenario while Table 3-9 is the site index. The resource is assumed to be similar to that at Long Valley so it, too, would benefit similarly from the key actions outlined for the previous scenario. The estimated cost range in 1985 also would be 27 to 33 mills/kWh when the first plant would go on line. However, because of the high industry interest and because the area is not as environmentally sensitive, it is assumed that development will proceed much more rapidly. The scenario indicates 600 MW_e on-line in 1990 and an expansion rate of 150 MW_e per year.

Table 3-9: 200 MW_e Site Index -- COSO Hot Springs Scenario

Site @ 200 MWe Each	Unit Numbers 50 MW_e Each	Lease Block	Comments
A	1, 3, 7, 13	I (1979)	Will probably let blocks I and II at same time
B	2, 5, 10, 16	↓	
C	4, 8, 14, 19		
D	6, 11, 17, 22		
E	9, 15, 20, 25	II (1982)	
F	12, 18, 23, 28	↓	
G	21, 26, 31, 35		
H	24, 29, 33, 37		
I	27, 32, 36, 39	Additions I to I	
J	30, 34, 38, 40	Additions II to II	

The critical requirement for the scenario is the joint effort by the Navy and the BLM to complete the leasing actions by early 1979.* Cooling water availability may also be a problem but only if total reinjection is required.

3. Eastern Sierra Subregion Program Requirements

Figure 3-13 summarizes the key program requirements to stimulate the growth of these two potentially large prospects. The two critical items are leasing and tax incentives. The technology being developed for the Geysers Hot Water resources would have application in the Eastern Sierra and, hence, are also shown. Finally, it is recommended that analysis be made of the issues on cooling water availability and the effect of transmission line availability and cost on geothermal development in the subregion.

Table 3-10 summarizes the near term regulatory and development activities associated with the two scenarios.

D. THE NORTHEAST SUBREGION

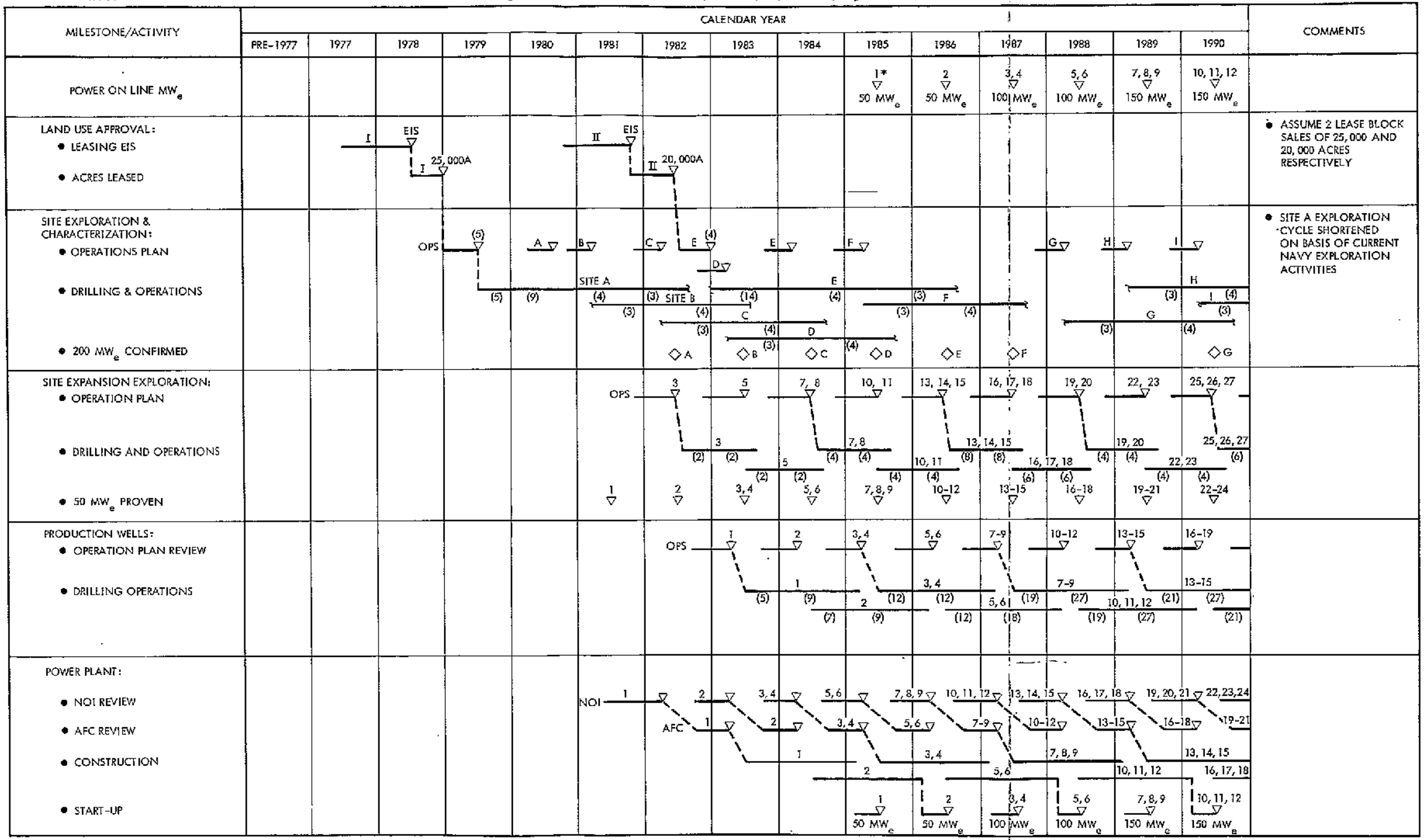
The Northeast subregion includes five KGRA's scattered through five counties: Glass Mountain KGRA in Siskiyou County; Lake City-Surprise Valley in Modoc County; Lassen straddling the Tehama-Plumas County line;

*Block II would probably be let on the same schedule as Block I.

RESOURCE ASSUMPTIONS:
- CAPACITY 2000 MW_c
- TEMPERATURE 220°C
- SALINITY LOW

[KGRA: PRIVATE LANDS ~8000 ACRES, BLM ~17,000, USN ~27,000]

LAND JURISDICTION: PRIMARILY FEDERAL



* NUMBERS WITHOUT PARENTHESIS ARE SITE IDENTIFICATION. THOSE WITH PARENTHESIS ARE QUANTITY REQUIRED.

Figure 3-12. Scenario Near Term Requirements Schedule COSO Hot Springs

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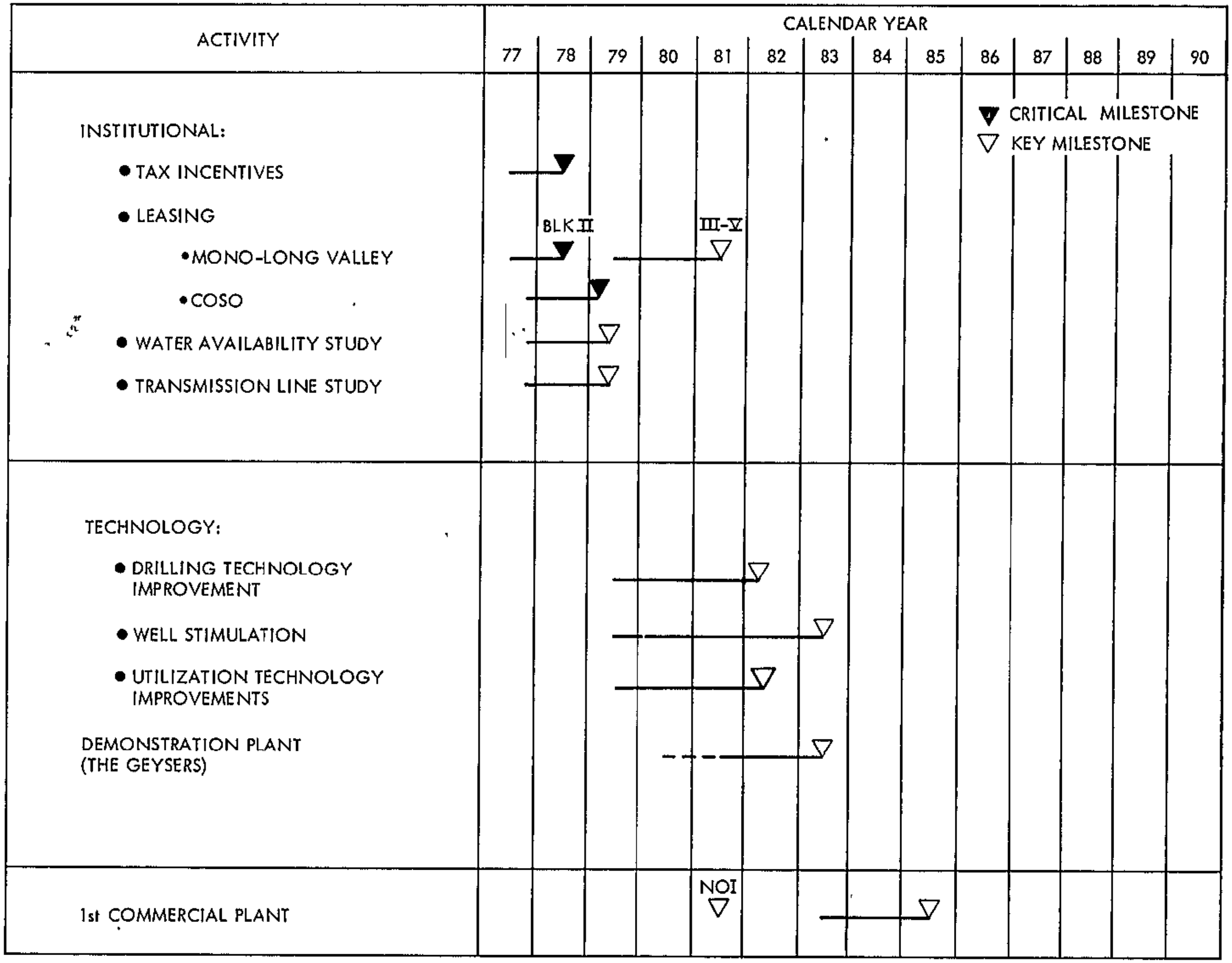

Figure 3-13. Eastern Sierra Subregion Program Requirements

Table 3-10. Scenario Near Term Development Activities -- Eastern Sierra Subregion

Milestone/Activity	Calendar Year Pre 1977	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
1. Environmental Approval															
• EIS's Initiated	1	1		1	1		1	1		1					
• EIR's Initiated															
2. Federal Acres Leased	<10,000		20,000	25,000		20,000	20,000		30,000			20,000			
3. Drilling Plan Review															
• Operation Plans			4	6	2	6	10	4	13	9	8	12	10	12	11
• "P" Reports															
4. Wells Drilled:															
• Exploration & Characterization				19	10	11	19	30	20	46	26	24	35	26	29
• Production								10	25	21	42	55	60	76	80
• Total	2*	—	—	19	10	11	19	40	45	64	68	79	85	102	109
5. Utility Commencement (NOI Filing) - Units						2	1	2	4	3	5	5	5	5	5
6. NOI/AFC Approval (Construction Initiated)								2	1	2	4	3	5	5	5
7. Power On-Line															
• Units Added									2	1	2	4	5	5	
• MW_e Added									100	50	100	200	150	250	
• MW_e Cumulative									100	150	250	450	600	850	

* 1976

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Wendel-Amedee in Lassen County; and Beckwourth Peak in Plumas County. Scenarios have been prepared for Lake City-Surprise Valley, Glass Mountain, Lassen and Wendel-Amedee.* The scenarios indicate that the first commercial power plants in the subregion will come on-line primarily in the post 1985 time period with the generating capacity reaching 700 MW_e by 1990, close to 2500 MW_e by 1995, and over 3700 MW by the year 2000. The development in this subregion is expected to benefit greatly from earlier developments in the remainder of the state. The timely leasing of the substantial federal lands will play an important role in the development of the subregion.

1. Northeast Subregion Overview

The Northeast subregion has been described by industry as "geologically very interesting". This is reflected in the large number of non-competitive lease applications filed. There is only limited resource assessment data for the subregion. There are numerous hot springs in the area. However, the estimated resource temperature associated with each is generally less than 150°C which could prove to be attractive in non-electric applications. The two identified resources with electrical potential (See Table 1-6) are at Surprise Valley and at Morgan Springs in the Lassen KGRA. Of the more than 195,000 acres associated with the scenarios, close to 90,000 are USFS lands and 35,000 acres BLM lands.

Most industrial activity to date has centered in the Surprise Valley and Wendel-Amedee areas. There has been considerable nonelectric interest at Susanville in the Wendell-Amedee area. The reservoir of water underlying the town in being used for geothermal heating. At Hobo Wells the resource has been successfully used to heat greenhouses for raising tomatoes. Recently a DOE sponsored study was completed on the feasibility of developing the geothermal resources in the Susanville area to attract new industries, create employment opportunities and increase the local revenue base.

The resource of Surprise Valley is estimated to be large, over 2000 MW_e, with a temperature near 175°C. Wells drilled near Lake City in the early 1960's by Magma Power found a resource with a temperature of 160°C (See Reference 13). Additional wells have been drilled in the 1970's by Magma, American Thermal Resources, and Gulf Oil Company but are either abandoned or idle. There are over 32,000 acres of private and state lands in the KGRA. The BLM offered 16 units and 34,000 acres of federal lands for lease in June of 1975. Bids were received and accepted on five tracts consisting of 10,000 acres. Currently there is little development activity in the area. The low resource temperature, the high drilling cost and the remoteness from major markets act as deterrents to near term development.

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*Beckwourth and other prospects are included in "Additional Prospects", Section III E.

Glass Mountain must be considered as a prime resource on the basis of the large number of lease applications in the area. While not included in the USGS assessment the resource could be large with temperatures near 200°C. The Glass Mountain KGRA consist of 33,000 acres, all USFS lands. The original KGRA of 15,000 acres was established on extensive geological evidence in the Medicine Lake area. 18,000 acres were added on the basis of overlapping lease applications. There are numerous non-competitive lease applications on lands adjacent to the KGRA. Because of the high industry interest the USFS has given leasing at Glass Mountain priority second only to Long Valley, and hopes to have the first block of leases let in the 1979-80 time period.

The Lassen KGRA located just south of the National Park also could be large with temperatures near 200°C. However, the two wells drilled at Kelley Hot Springs were not successful. Assessment and confirmation data on the true extent of the resource is lacking. The Lassen KGRA consist of 79,000 acres: 24,000 private and state; and 55,000 USFS. There have been non-competitive lease applications on 17,000 additional acres outside the KGRA. Currently, there are no firm plans to proceed with the leasing necessary for development.

Shallow exploration wells drilled in the Wendel-Amedee area did not indicate temperatures substantially above boiling; however, temperatures at depth are not yet known. There is substantial industrial interest in the area. The KGRA consist of 17,000 acres with only 4,000 acres of federal lands. Non-competitive lease applications have been filed on an additional 7000 acres in the area. The EAR for the potential lease sale is in the review process.

2. Northeast Scenario Definition and Rationale

a. Lake City - Surprise Valley. Figure 3-14 is the near term requirements schedule for the Lake City - Surprise Valley scenario. Table 3-11 is the site index. The first commercial plant is shown on-line in 1983. The current estimated cost of power for this prospect ranges from 46 to 62 mills/kWh. The need to construct transmission lines could further increase the cost of power. With the tax incentives this could be reduced from 39 to 51 mills/kWh. To bring the costs down the following set of actions may be necessary in addition to the tax incentives:

(1) Reduce drilling costs.

(2) Improve well flow.

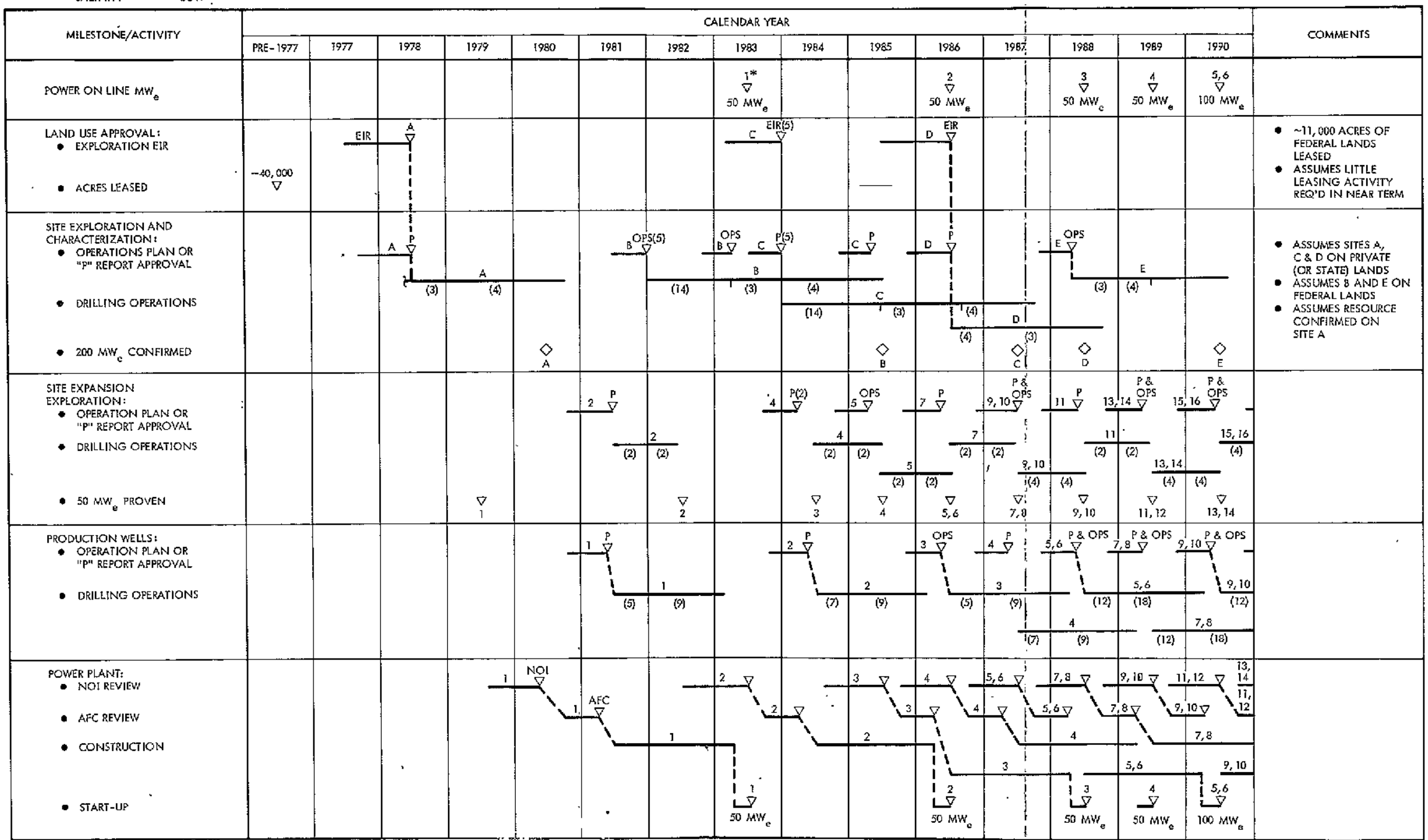
(3) Improve conversion cycle efficiency.

Because of the lower temperature it is assumed that binary technology will be required which won't be demonstrated until 1981. It is necessary to file the NOI in 1979 for the plant in 1983. Considering the actions required to reduce the cost the 1983 commercialization data may be optimistic. However, it is not unreasonable to expect that 300 MW_e can be on lines by 1990 as is indicated in the scenario.

RESOURCE ASSUMPTIONS:
- CAPACITY 2000 MW_e
- TEMPERATURE ~175°C
- SALINITY LOW

[KGRA: PRIVATE-STATE ~32,000 ACRES, BLM ~32,000, USFS ~2,000]

JURISDICTION:
- COUNTY
- STATE
- FEDERAL



*NUMBERS WITHOUT PARENTHESIS ARE SITE IDENTIFICATION. THOSE WITH PARENTHESIS ARE QUANITY REQUIRED.

Figure 3-14. Scenario Near Term Requirements Schedule Lake City - Surprise Valley

Table 3-11. 200 MW_e Site Index Lake City - Surprise Valley Scenario

Site @200 MW_e Each	Unit Numbers 50 MW_e Each	Lease Block	Comments
A	1, 2, 4, 7	Private/State Lands	11,000 Acres BLM Lands Leased
B	3, 5, 9, 13	Existing Fed Leases	
C	6, 10, 14, 17	Private/State Lands	
D	8, 11, 15, 19	↓	
E	12, 16, 20, 23	Existing Fed Leases	
F	18, 21, 25, 29	Undefined	
G	22, 26, 30, 33		
H	24, 27, 31, 35		
I	28, 32, 36, 38		
J	34, 37, 39, 40	↓	

b. Glass Mountain. Figure 3-15 is the near term development requirements schedule and Table 3-12 the site index for the Glass Mountain scenario. Because the associated lands are under federal jurisdiction the development is paced by leasing. If the leases can be let by 1980 then the first plant can be on line in 1987. The NOI for the plant would have to be filed by late 1983. As a result the development of the Glass Mountain resource could benefit from demonstrations at Heber in 1981 and potentially the Geysers in 1983 and also the technological advances required for other prospects. It is expected, therefore, that the current estimated cost range of 39 to 51 mills/kWh could be reduced to 29 to 36 mills/kWh by 1985. This would make it competitive with alternate sources of energy. If so, then 200 MWe could be on line by 1990 and the full estimated 1000 MW_e potential by the year 2000.

c. Lassen. Figure 3-16 and Table 3-13 are the near term development requirements schedule and site index, respectively. The schedule and requirements for Lassen are similar to those for Glass Mountain. Leasing of the federal lands is required in 1980 for the first commercial plant in 1987 but currently is not scheduled. Increased priority is required within the USFS. It is estimated that by 1985 the cost of power can range from 27 to 33 mills/kWh assuming successful technology development and demonstration programs.

Table 3-12. 200 MW_e Site Assumptions Glass Mountain Scenario

Site @200 MW_e Each	Unit Numbers 50 MW_e Each	Lease Block and Need Date	Comments
A	1, 2, 5, 9	I (1980)	USFS is Considering
B	3, 7, 11, 15	↓	Leasing as One Large
C	4, 8, 12, 16		Block in 1980 Rather
D	6, 10, 13, 17	II (1984)	Than Two Small
E	14, 18, 19, 20	↓	Blocks

d. Wendel-Amedee. Figure 3-17 is the development requirements schedule for the Wendel-Amedee scenario. Table 3-14 is the site index. The first plant is shown to be on-line in 1988 primarily because of the low estimated resource temperature of <175°C and the need for considerable technological advances to get the cost range down to 31 to 40 mills/kWh. If the leasing of the federal lands can be completed in 1978, which appears possible, this first plant could probably be moved up to 1985. It is assumed that the development of Wendel-Amedee will also use binary technology and will require:

(1) Tax incentives.

(2) Reduced drilling costs.

(3) Improved well flow.

(4) Improved conversion cycle efficiency.

Table 3-13. 200 MW_e Site Index Lassen Scenario

Site @200 MW_e Each	Unit Numbers 50 MW_e Each	Lease Block	Lease Block Location
A	1, 2, 5, 9	I (1980)	USFS is Considering
B	3, 7, 11, 15	Private Lands	Leasing as One Large
C	4, 8, 12, 16	I (1980)	Block in 1980 Rather
D	6, 10, 13, 17	II (1984)	Than Two Smaller
E	14, 18, 19, 20	↓	Blocks

RESOURCE ASSUMPTIONS:
- CAPACITY 1000 MW_e
- TEMPERATURE 200°C
- SALINITY LOW

[KGRA: PRIVATE ~1,000, USFS ~33,000]

JURISDICTION: PRIMARILY FEDERAL

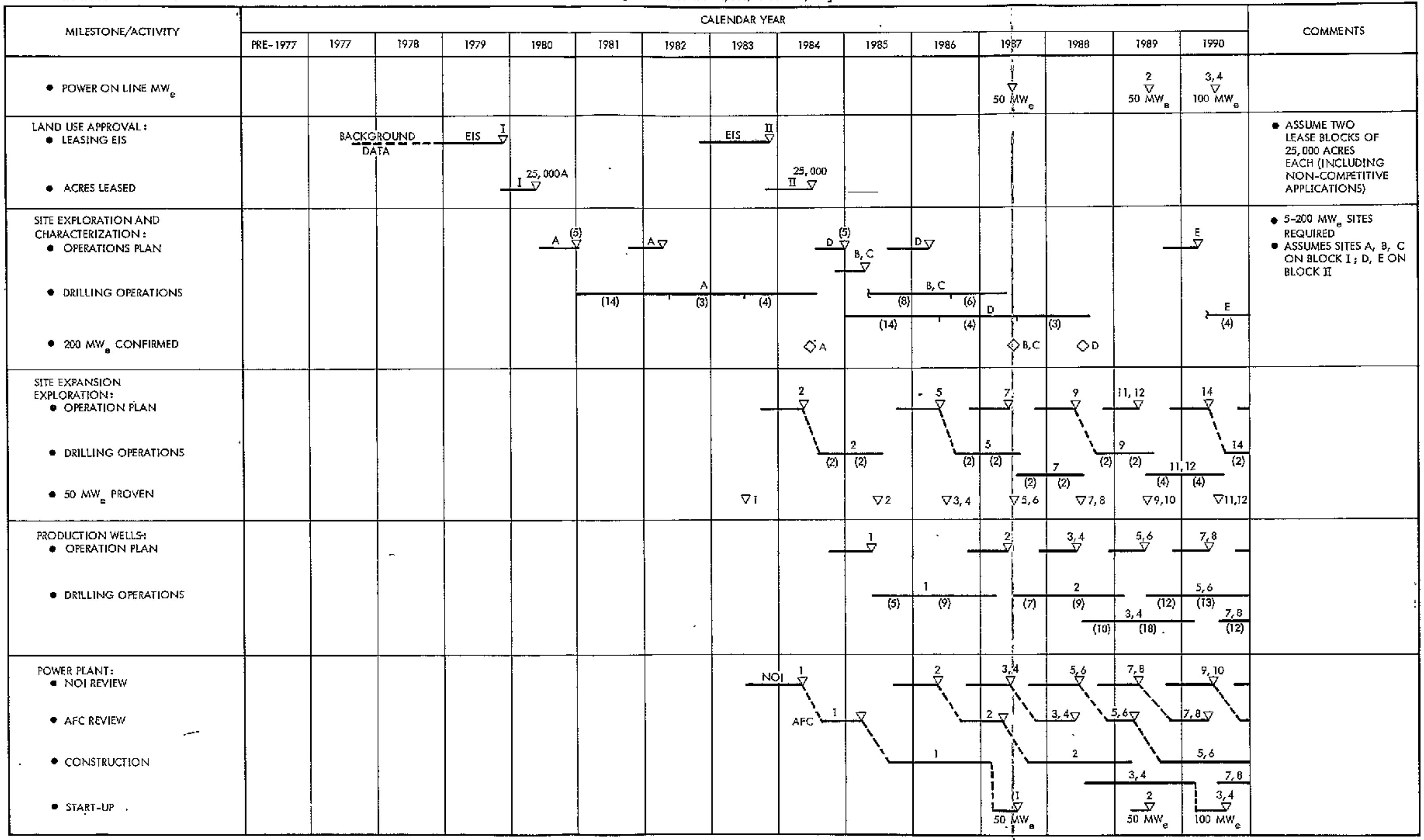


Figure 3-15. Scenario Near Term Requirements Schedule Glass Mountain

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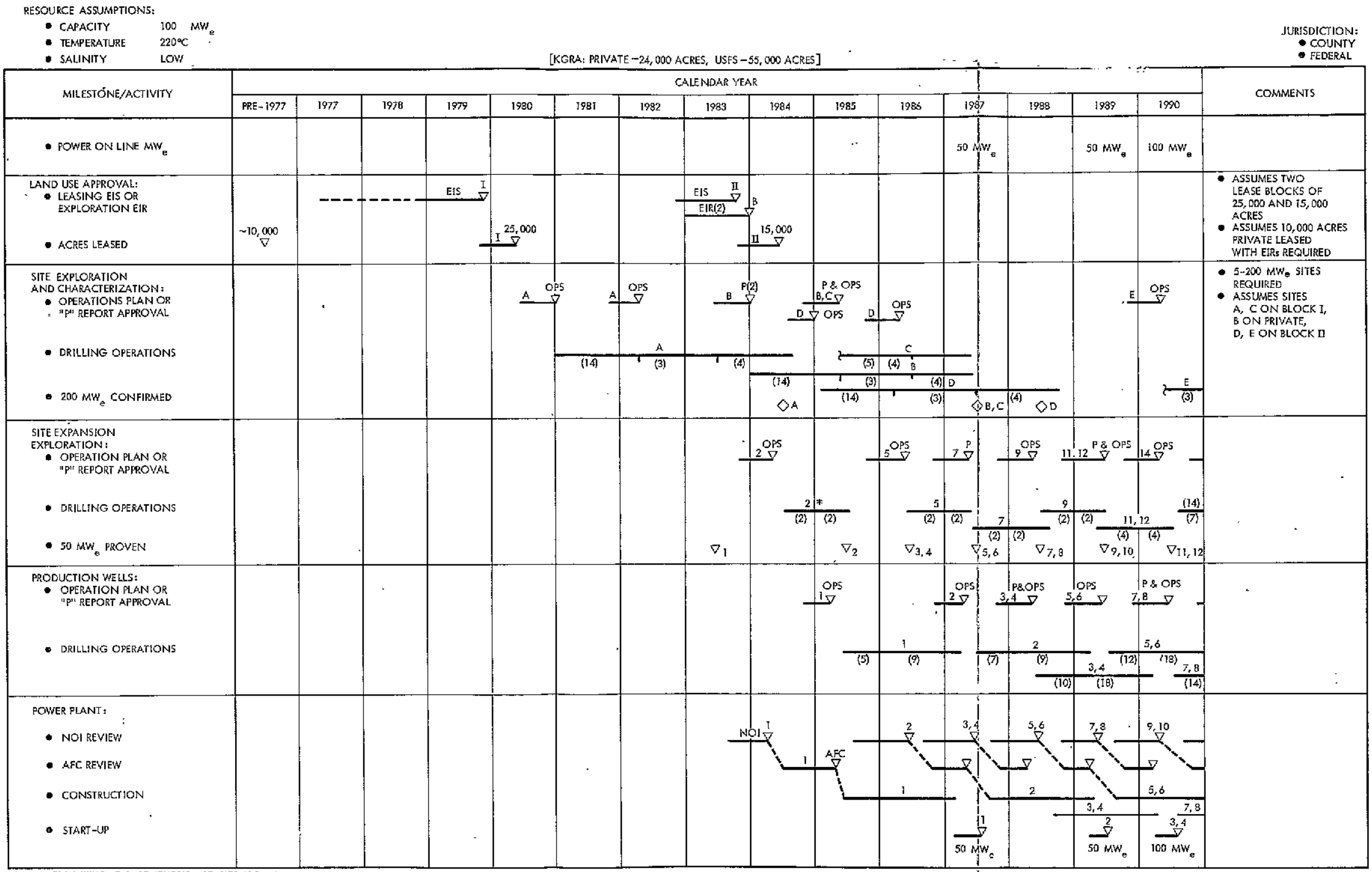

* NUMBERS WITHOUT PARENTHESIS ARE SITE IDENTIFICATION. THOSE WITH PARENTHESIS ARE QUANTITY REQUIRED.

Figure 3-16. Scenario Near Term Requirements Schedule Lassen

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RESOURCE ASSUMPTIONS:
- CAPACITY 500 MW_e
- TEMPERATURE 175°C
- SALINITY LOW

JURISDICTION:
- COUNTY
- FEDERAL

[KGRA: PRIVATE -13,000 ACRES; BLM-4,000]

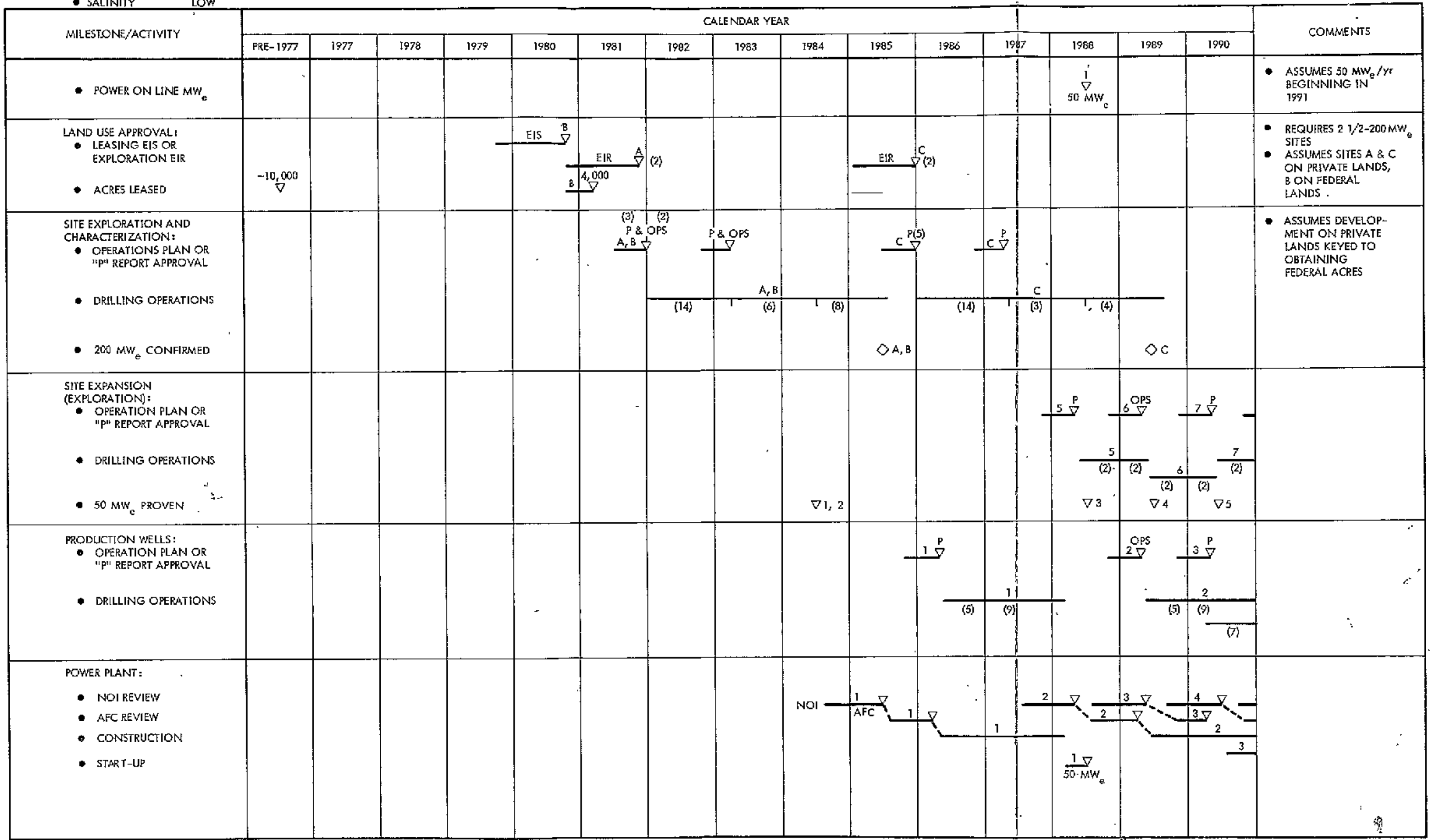

Figure 3-17. Scenario Near Term Requirements Schedule Wendel-Amedee

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Table 3-14. 200 MW_e Site Index Wendel-Amedee Scenario

Site @200 MW_e Each	Unit Numbers 50 MW_e Each	Lease Block	Comments
A	1, 4, 7, 9	Private Lands	Federal Lands Could Be Leased by First of 1978 on Current BLM Schedule
B	2, 5, 8, 10	I (1981)	
C	3, 6	Private Lands	

3. Northeast Subregion Program Requirements

Table 3-15 summarizes the near term regulatory and development activities associated with the four scenarios. Figure 3-18 summarizes the key program requirements to stimulate the postulated growth. The critical program elements include:

(1) Tax incentives.

(2) Leasing at Glass Mountain and Lassen.

(3) Binary demonstration plant at Heber and associated technology advances.

The NOI for the 1983 commercial plant at Lake City-Surprise Valley would have to be filed two years before the demonstration plant would be on line. The schedules for the first plants at the other three prospects are not as tight.

It is recommended that the effect of transmission line availability and cost on developments in the Northeast be examined in more detail.

E. ADDITIONAL PROSPECTS

1. Overview

The previous parts of Section III presented detailed scenarios on 12 prospects with an assumed potential of 17,000 MW_e for 30 years. By no means is it believed that these prospects constitute the extent of the state's geothermal potential. Instead it is expected that future exploration will expand the states identified resource base considerably as a result of:

(1) New knowledge of the extent of an already identified system that increases its estimated volume appreciably.

(2) The temperature of an identified system being higher than estimated.

(3) The discovery of a previously unknown system.

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Table 3-15. Scenario Near Term Development Activities Northeast Region

Milestone/Activity	Pre 1977	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
	CALENDAR YEAR														
1. Environmental Approval															
• EIS's Initiated			2	1			2								
• EIR's Initiated		1			2			7		3					
2. Federal Acres Leased					54,000				40,000						
3. Drilling Plan Review															
• Operation Plans					6	9	2	2	12	5	4	7	11	8	9
• "P" Reports		1			2	3	1	10	2	8	4	4	3	4	4
4. Wells Drilled															
• Exploration & Characterization			3	4		30	36	17	46	53	51	26	23	26	27
• Production						5	9		7	19	28	39	59	95	108
• Total	0*		3	4		35	45	17	53	72	79	65	82	121	135
5. Utility Commitment (NOI Filing) - Units				1			2	2	2	3	6	7	7	7	7
6. NOI/AFC Approval (Construction Initiated)						1			2	2	2	3	6	7	7
7. Power On-Line															
• Units Added								1			2	2	2	3	6
• MW_e Added								50			100	100	100	150	300
• MW_e Cumulative								50			150	250	350	500	800

*1976

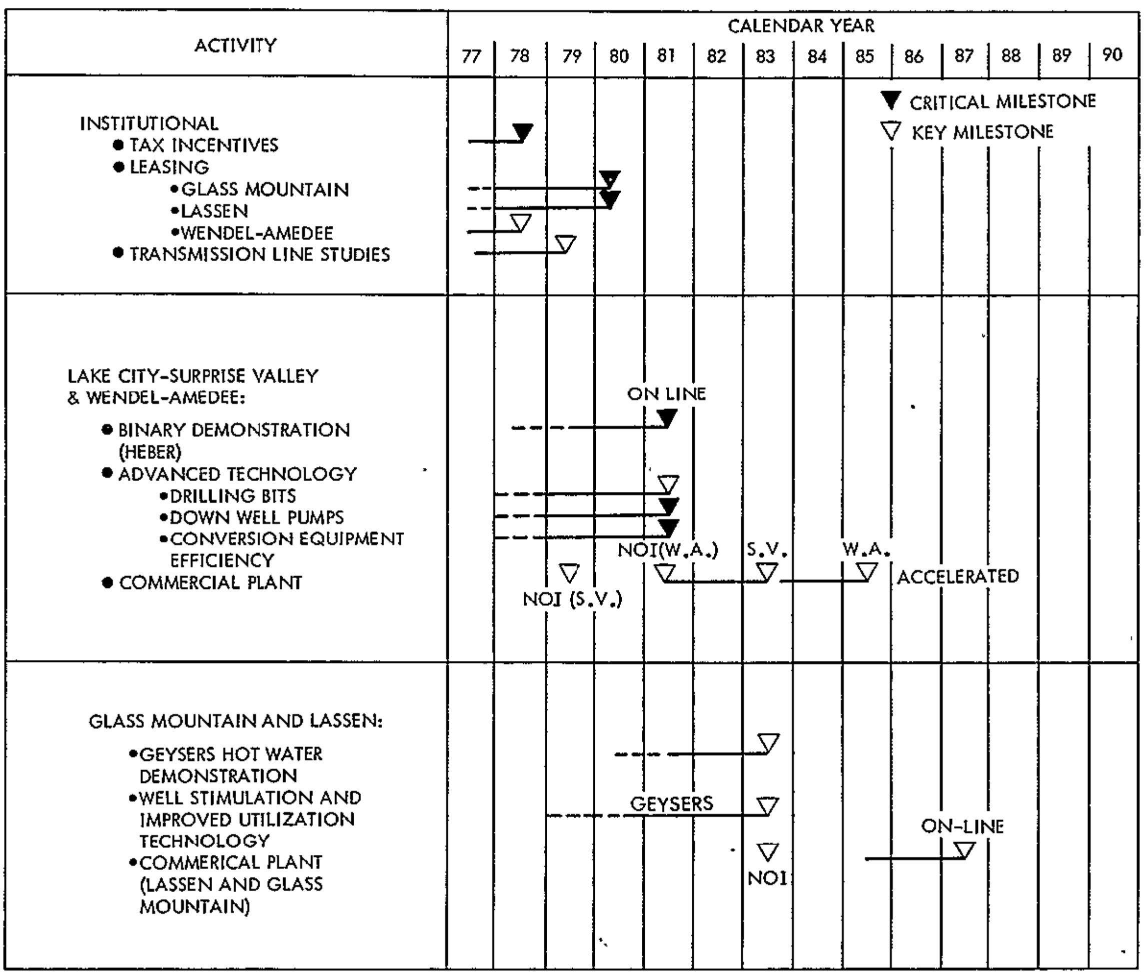

Figure 3-18. Northeast Subregion Program Requirements

In the context of this report categories 1 and 2 are applicable to the resource estimates associated with the twelve sites specific scenarios. Category 3 would apply to those other identified sites in the state not specifically considered and new sites yet to be discovered. In the light of the limited extent of drilling that has occurred outside of the main Geysers steam field, the uncertainty on the current estimates is large. On the basis of the number of known sites in the state that were not included in the 12 scenarios there is a high probability of substantial new discoveries. These known sites include other KGRA's, the Diablo region and numerous hot springs throughout the state (Reference 18) which were not included in the USGS assessment. The importance of these "additional prospects" is best illustrated in Figure 1-1 which shows their potential contribution in the post 1985 time period. To support this level of growth it is important to increase the number of identified prospects in the state over the current twelve and to develop prospect specific plans for their development. The "Additional Scenario" identifies the types of actions necessary to expand our current knowledge of the resource and to develop these new prospects.

2. Additional Prospects Scenario Rationale and Program Requirements

Figure 3-19 presents the near term requirements to identify and develop new prospects or expand currently identified resources. Table 3-16 is the site index which is quite speculative. Table 3-17 summarizes the development activities. The key is to encourage exploration which can be achieved by:

(1) Providing tax incentives.

(2) Facilitating leasing.

(3) Facilitating the environmental review and permitting process.

Recognizing how little is truly known of the states resource potential, it is proposed that resource assessment activities be increased substantially in the rest of the 1970's; perhaps utilizing state agencies, universities and colleges. Prime attention needs to be given to the other KGRA's in the state and the geologically interesting Diablo Range east of San Jose. This assessment paces the establishment leasing priorities and schedules for the federal lands involved.

JURISDICTION:
- COUNTY
- STATE
- FEDERAL

RESOURCE ASSUMPTIONS:
- CAPACITY 13,000 MW_e
- TEMPERATURE UNDEFINED

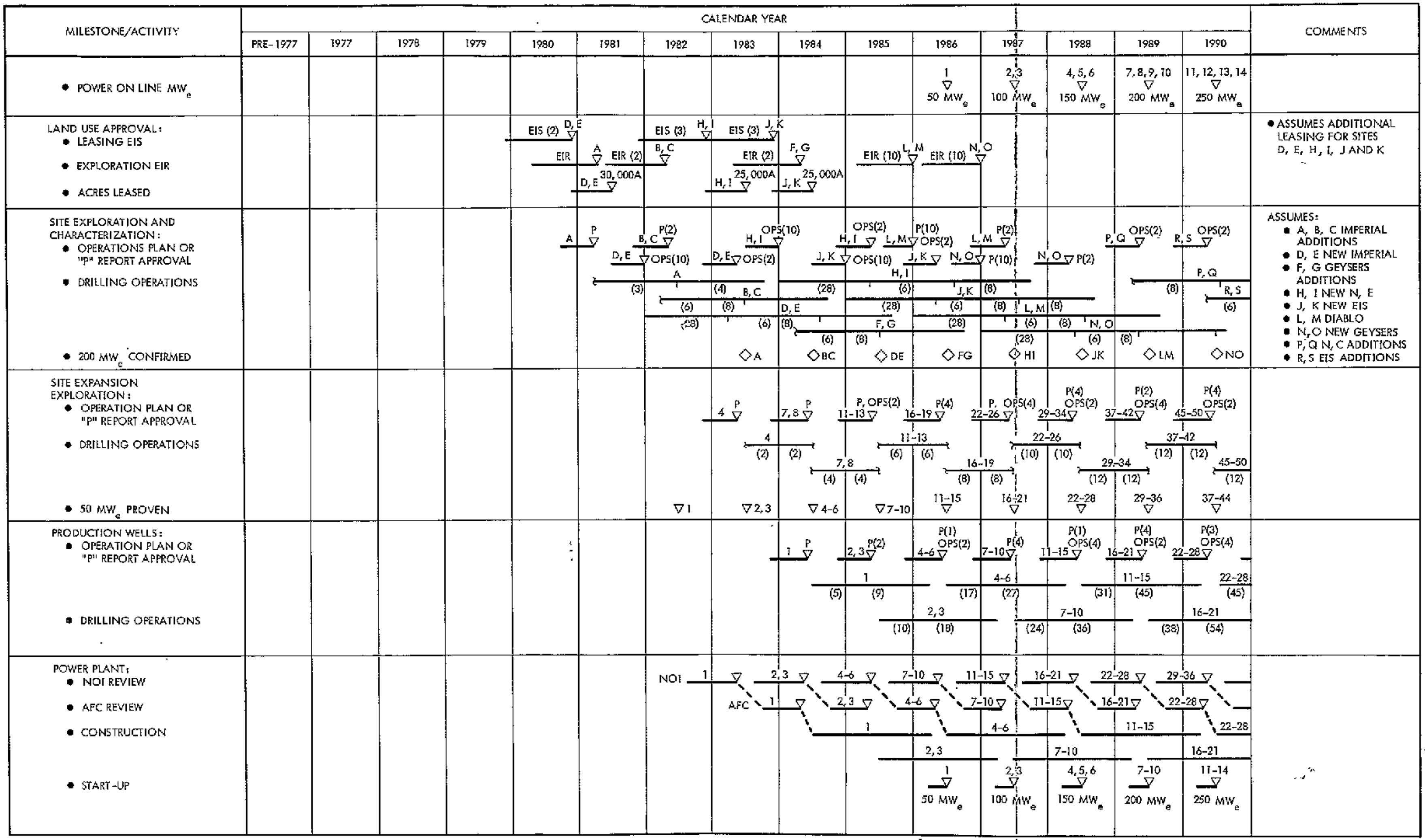

Figure 3-19. Scenario Near Term Requirements Schedule Additional Prospects

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Table 3-17. Scenario Near Term Development Activities Additional Prospects

Milestone/Activity	Pre 1977	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Comments
							CALENDAR YEAR									
1. Environmental Approval																
• EIS's				2		3	3									
• EIR's					1	2		2		5	5					
2. Federal Acres Leased						30,000		25,000	25,000							
3. Drilling Plan Review																
• Operation Plans						6	2	5	9	4	4	6	8	8	8	
• "P" Reports					1	2	1	3	3	10	12	17	6	7	6	
4. Wells Drilled																
• Exploration & Characterization						3	38	16	48	52	58	60	36	38	38	
• Production	—	—	—	—	—	—	—	—	5	19	35	51	67	83	99	
• Total						3	38	16	53	71	93	111	103	121	137	
5. Utility Commitment (NOI Filing) - Units							1	2	3	4	5	6	7	7	7	
6. NOI/AFC Approval (Construction Initiated)									1	2	3	4	5	6	7	
7. Power On-Line																
• Units Added											1	2	3	4	5	
• MW_e Added											50	100	150	200	250	
• MW_e Cumulative											50	150	300	500	750	

Table 3-16. 200 MW_e Site Index Additional Prospects Scenario

Site @200 MW_e Each	Unit Numbers 50 MW_3 Each	Lease Block Need Date	Comments
A	1, 4, 11, 22	Additions to East Mesa, Heber Salton Sea and Brawley	
B	2, 7, 16, 29		
C	3, 8, 17, 30		
D	5, 12, 23, 37	Glamis, Dunes, Ford Dry Lake (1981)	
E	6, 13, 24, 38		
F	9, 18, 31, 45	Additions to Geysers Storm Field	
G	10, 19, 32, 46		
H	14, 25, 39, 53	New Sites in Northeast (1984)	To be Identified
I	15, 26, 40, 54		
J	20, 33, 47, 61	New Sites in Eastern Sierra (1985)	To be Identified
K	21, 34, 48, 62		
L	27, 41, 55, 69	Assumed Central Coast	Possibly Diablo Range
M	28, 42, 56, 70		
N	35, 49, 63, 77	New Geyser Subregion Sites	To be Identified
O	36, 50, 64, 78		
P	43, 57, 71, 85	Additions to Identified Northeast Sites	
Q	44, 58, 72, 86		
R	51, 65, 79, 93	Additions to Identified Eastern Sierra Sites	
S	52, 66, 80, 94		

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2. "Economic Analyses of Geothermal Energy Development in California" by G. (Ram) Ramachandrau, The Stanford Research Institute, May 1977.

3. "Geothermal Energy Resources in California: Status Report" Jet Propulsion Laboratory Document 5040-25 prepared for the California Energy Resources Conservation and Development Commission Research and Development Division, June 30, 1976.

4. "Assessment of Geothermal Resources of the United States - 1975." Geological Survey Circular 726, U.S. Geological National Center, Reston, Virginia.

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7. Geothermal Energy Magazine, Page 8, Vol. 5, No. 5, May 1977, "Summary of 1976 Geothermal Drilling - Western United States," J. L. Smith, C. F. Isselhardt, J. S. Matlick, Republic Geothermal, Inc.

8. "Costs of Geothermal Development", Tod Larson, Dry Lands Research Institute, U.C.-Riverside Memo 206.6 A-D, July 1976.

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11. Meeting at USGS, Menlo Park, June 21, 1977.

12. Private Communication, D. Anderson, CERCDC.

13. "The Potential of Low Temperature Geothermal Resources in Northern California" by Judith Hannah, California Division of Oil and Gas, Report No. TR 13, 1975.

14. "Rule 56.1 Geothermal Operations - Power Plant Emissions", Northern Sources County Air Pollution Control District, 1976.

15. Private Communication, G. Gould, USFS.

16. "Impediments to Geothermal Development in Lake County, California" by Elaine T. Hussey, Jet Propulsion Laboratory Working Paper 5, December 1, 1976.

17. "Comparison of Brine Production Methods and Conversion Processes for Geothermal Electric Power Generation" by D. G. Elliott, Environmental Quality Laboratory Report No. 16, California Institute of Technology, July 1975.

18. "Thermal Springs of the United States and Other Countries of the World - A Summary" G. A. Waring, U.S. Geological Survey Paper 492 (1965).

APPENDIX A

REQUIREMENTS DEFINITION METHODOLOGY

APPENDIX A

REQUIREMENTS DEFINITION METHODOLOGY

A two-phase, goal-oriented approach was used in defining the requirements for accelerating geothermal energy development in California. The first phase focused on the definition of potential growth scenarios for various identified resources in the state. In the second phase, the scenarios were analyzed and programmatic actions necessary for the realization of the postulated scenarios were defined. Three advisory panels* representing industry, federal and state regulatory agencies and local government and environmental groups, were established to guide the efforts. This appendix summarizes the methodology and main sources of data used in each of the two phases.

A. SCENARIO DEFINITION PHASE

The various prospect scenarios were developed through a five-step process as depicted in Figure A-1. First, the twelve prospects were identified based on estimated potential and industry interest as demonstrated by leasing, exploration and development activities. Second, both resource quality (i.e. temperature <u>and</u> salinity) and resource potential were established based primarily on USGS data and the inputs of the industry panel. As is discussed in Section I-B-1, the quality of the resource data ranges from quite good where extensive drilling has occurred to quite speculative where little data exists. Third, an estimate was made of the earliest year that a power plant could be on-line for each prospect. This estimate was based on current industry plans when available or on an assessment of current development status, technology availability, and the considerations of marketability** and environmental sensitivity. The data for this assessment was drawn from the comments of the three panels, existing status data (See Reference 3) and SRI economic analysis (Reference 2). Fourth, the growth rate in MW_e per year was estimated again based on resource marketability and environmental sensitivity. Fifth, given the year of the first plant-on-line and the estimated growth rate, the power on-line scenario were completed for each prospect.

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*For panel membership refer to Appendix C.

**Marketability includes such factors as resource quality and magnitude, estimated costs, transmission line availability and demonstrated industrial interest.

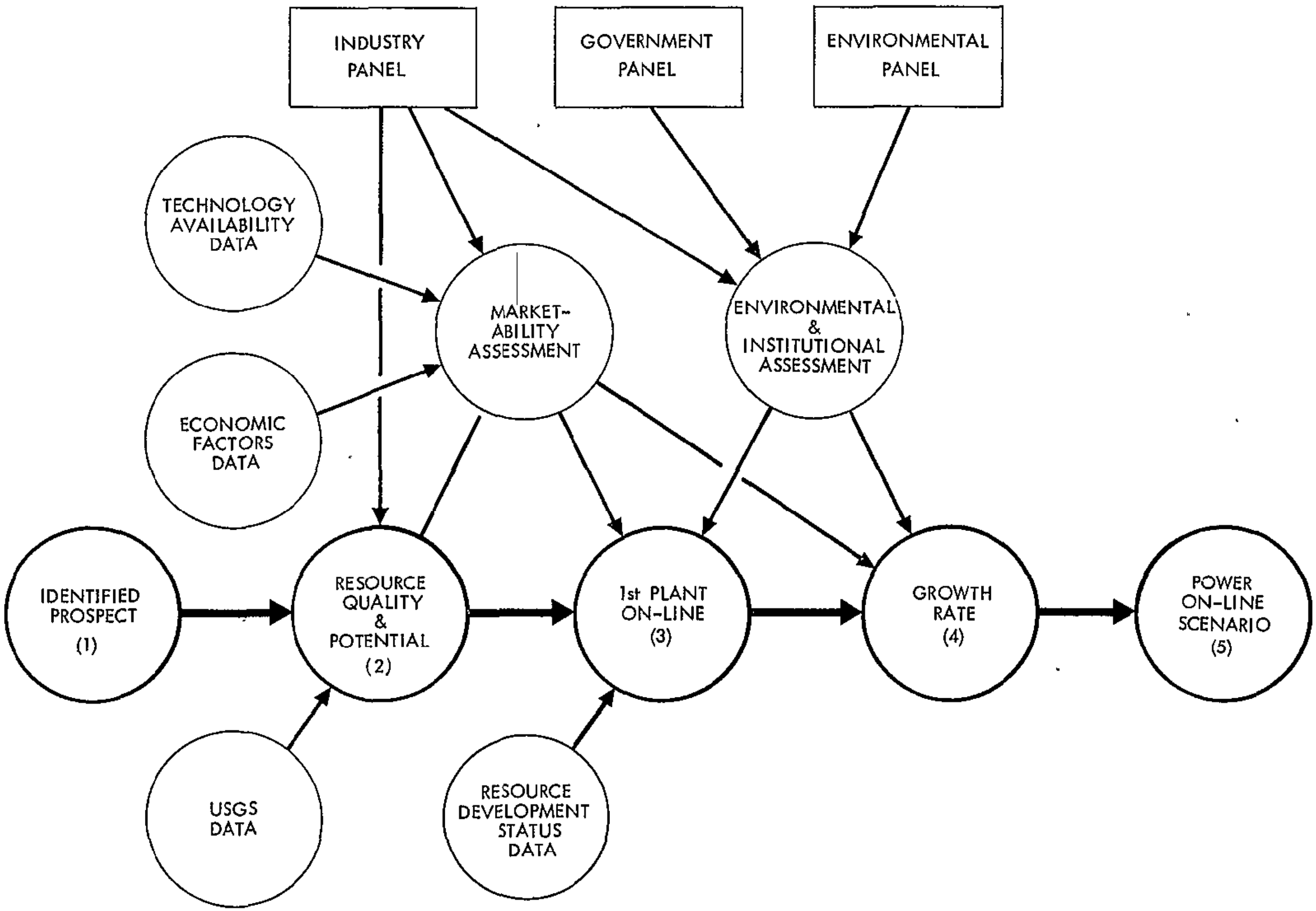

Figure A-1. Scenario Definitions

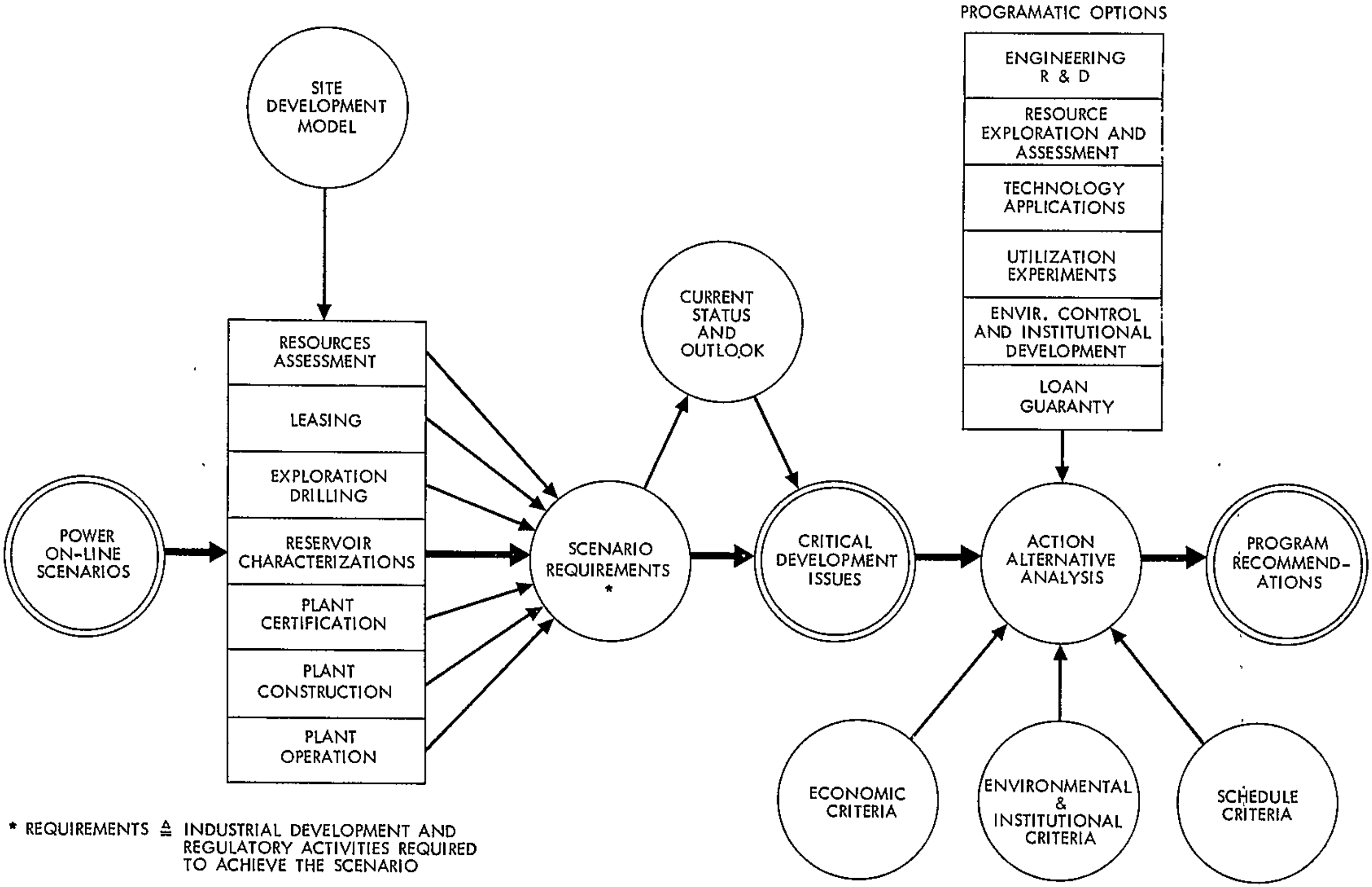

Figure A-2. Scenario Analysis and Recommendation Phase

77-63

B. SCENARIO ANALYSIS AND RECOMMENDATIONS

Based on a given scenario, Figure A-2 depicts the process then followed in developing the recommendations for accelerating geothermal energy development in California. First, scenario requirements schedules were developed using the site development model (Appendix B) which shows the development and regulatory activities required to bring each 50 MW_e increment of power on-line. These scenario requirements were examined against the current development status and outlook to define those factors or issues which are (or will be) limiting development. These critical issues could include technical, economic, legal, environmental or institutional factors. There are a number of potential options available within the federal geothermal energy program to help solve the existing problems*. Then, for each of the critical issues options were examined and evaluated on the basis of schedule requirements, economics, environmental, and institutional constraints. For example, if the schedule provided sufficient time for technology R&D to reduce the cost of the first plant, the technology R&D was proposed. If not, then cost-shared pilot or demonstration plants were proposed with the technology directed to the second plant on-line. The philosophy behind the recommendations was to provide the required assistance to industry and the responsible agencies. The result of this process was the definition of program recommendations necessary to realize each of the postulated scenarios.

*Definition Report: "Geothermal Energy Research, Development and Demonstration Program" DOE-86, October 1975.

APPENDIX B

SCENARIO REQUIREMENT ASSUMPTIONS

APPENDIX B

SCENARIO REQUIREMENT ASSUMPTIONS

This appendix summarizes the key assumptions used in the development of the scenarios, including: exploration, characterization and production well drilling requirements; leasing acreage assumptions; cooling-water assumptions; and 200 MW_e site-development schedule assumptions.

A. 200 MW_e SITE DEVELOPMENT DRILLING ASSUMPTIONS

Industry has indicated that the "rule of thumb" minimum reservoir size in which they would be interested is 200 MW_e (for 30 years). This is the basic reservoir increment that has been assumed for the scenario analysis. Greider, in his analysis of prospect and exploratory drilling requirements*, indicates that of 16 prospects promising enough for exploratory drilling, only one will prove to be the commercially viable 200 MW_e field. This 16 to 1 success ratio, according to Greider, is better than the industry average. In this report, the scenarios are based on the development of the most promising prospects in the state which hopefully prove to be better than the past average. Therefore, the somewhat more optimistic assumptions illustrated in Figure B-1 were used in defining site and drilling requirements for the scenarios. For new prospects, it was assumed that only 10 sites would have to be deep drilled to discover the 200 MW_e prospect. The total number of exploratory wells required for the 10 sites would be a minimum of 14. It was then assumed that 7 additional wells would be required to characterize the resource, "prove" the first 50 MW_e, and establish the 200 MW_e potential. An additional 4 wells would be required to "prove" each successive 50 MW_e increment. Finally, it was assumed that typically a total of 20 wells (16 production and 4 reinjection) would be required for each 50 MW_e increment for the hot-water resources.** Therefore, in addition to the exploration and characterization wells, 14 more wells would be required for the production of the first 50 MW_e increment and 16 wells for each successive increment. The total number of wells required to discover, characterize and produce the first 200 MW_e of hot-water resources for new prospects would be 95. For the expansion of proven prospects it was assumed that only 5 sites would have to be explored (deep drilled) to prove each successive 200 MW_e increment. For the expansion of The Geysers steam field it was assumed that 8 characterization and 14 additional production wells would be required for each 100 MW_e added.

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*"Status of Economics and Financing of Geothermal Energy Power Production," R. Greider, Geothermal Resources Council, Davis, Calif., Sept. 1976.

**This is representative for a 180°C well-head temperature resource and a flow rate of 500,000 lbs/h. It can vary significantly with temperature and flow rate.

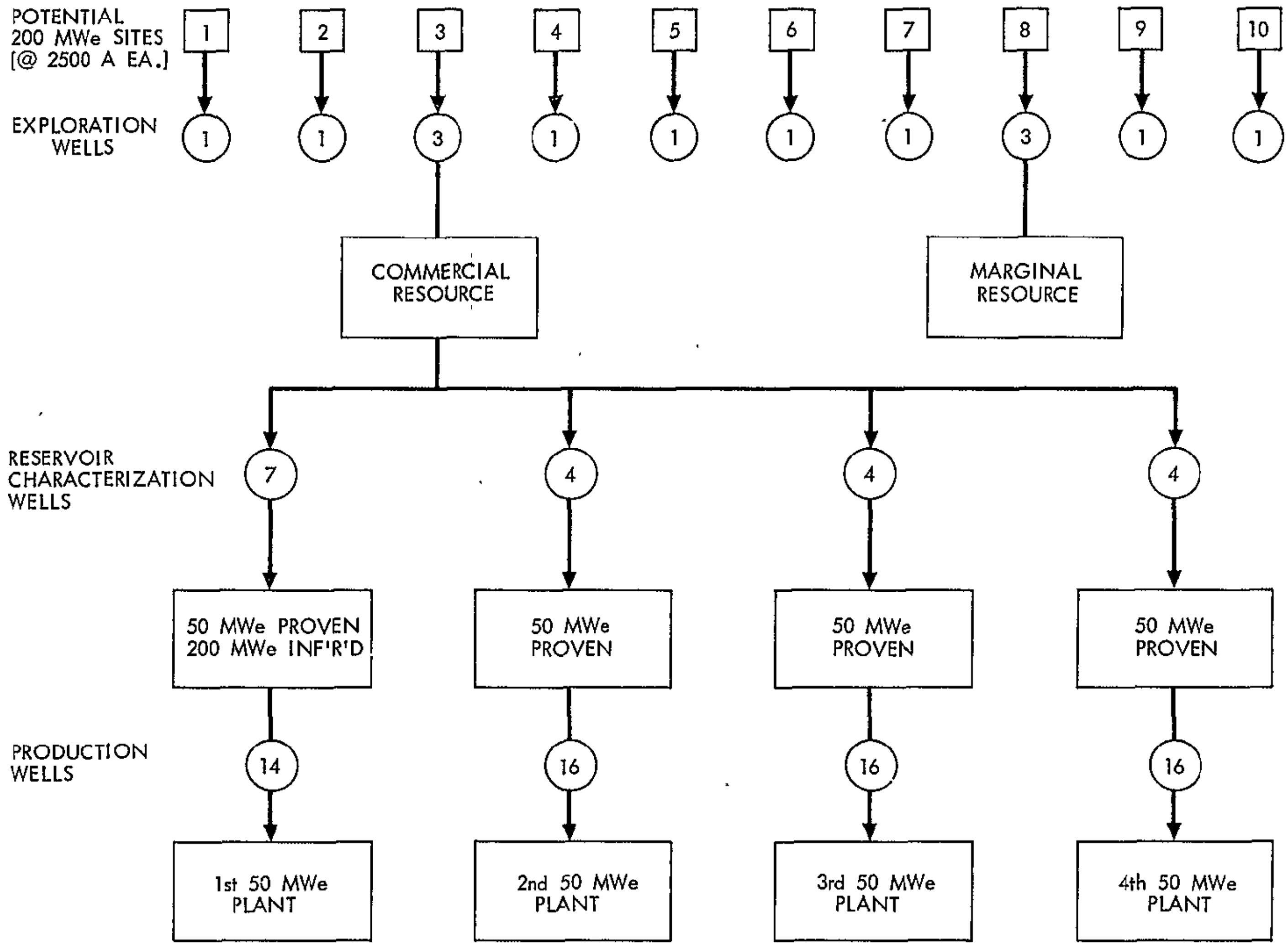

Figure B-1. 200 MW_e Site Development Drilling Assumptions (Hot-Water)

B. LEASING ACREAGE REQUIREMENTS

The leasing acreage requirements were derived from Figure B-1 assuming a production well spacing of 40 acres per well and a development density of 50%. (The development density is the ratio of the acres developed to the acres leased for a 200 MW_e site.) These assumptions result in a requirement for approximately 2500 acres for each 200 MW_e site for the hot-water resources. Because only 1 in 10 sites proves to be commercially viable 25,000 acres would have to be leased for the first 200 MW_e in new prospects and 12,500 acres for each subsequent 200 MW_e of potential. The acreage requirements for the steam resources would be half that of the hot-water resources.

C. COOLING WATER REQUIREMENTS

It is assumed that evaporative cooling towers will be used in geothermal power plants as they act to improve the cycle efficiency and reduce cooling water requirements. The source of the make-up water for the plant can be the condensed steam for a flashed-steam plant where total re-injection is not required. When total re-injection is required or the flashed steam cycle is <u>not</u> used, supplemental cooling water must be supplied. Goldsmith* has calculated the supplemental cooling water requirements as a function of reservoir temperature for flashed steam and binary technology plants. These data are summarized in Table B-1. For this report, a typical 7000 acre feet/year of make-up water per year was assumed for a 100 MW_e plant operating at an availability factor of 0.80.

Table B-1. Make Up Water Requirements

Reservoir Temp (^{o}C)	150	200	250	300
Flashed steam ($\frac{\text{acre-ft}}{\text{yr-MW}_e}$)	97	61	50	41
Binary "	167	101	77	60

*"Engineering Aspects of Geothermal Development in the Imperial Valley". by Martin Goldsmith, EQL Memorandum No. 20, California Institute of Technology, December 1976.

D. 200 MW_e SITE DEVELOPMENT SCHEDULE

Figures 2-11 and 2-12 show the assumed development timelines for private and federal lands in California. There are five phases of industrial activity associated with bringing the first power plant on line for a new prospect. These are:

(1) Geophysical Survey: to assess various prospects and determine exploratory well locations. (Six to twelve months assumed required.)

(2) Exploratory Drilling: to "discover" the viable reservoir. The drilling of temperature-gradient wells could procede the drilling of the three deep exploratory wells needed to prove the resource existence. (Eighteen months assumed required.)

(3) Reservoir Characterization: to evaluate the properties of the resource and its extent. This phase could include extended flow and reinjection tests and the drilling of additional wells (7 assumed) to prove at least a 200 MW_e potential. (Twenty-six months assumed required.).

(4) Power Plant Design: including both preliminary and detailed design phases conducted by the utility in conjunction with the field developer, to evaluate designs options and finalize the detailed design of the plant based on reservoir characteristics and available technology. (Thirty months assumed initiated in parallel with the reservoir characterization work.)

(5) Power Plant Construction: including field development (Twenty-eight months assumed required including six months for start-up.)

Assuming the power plant design can be initiated in parallel with the reservoir characterization and plant construction phases, then a little over six years are assumed to be required to get the first plant on line starting from the initiation of the exploration drilling phase.

The exploration and plant construction phases are regulated by various state, federal and local agencies. The key regulatory steps are:

(1) The Environmental Review (EIR or EIS and associated drilling permits) prior to initial exploratory drilling. On private lands this phase can be completed in one year if adequate environmental baseline data exits. If not, another year could be required to gather the necessary data. On federal lands, an additional year could be required for the leasing process and the review of operations plans.

(2) Reservoir Characterization Drilling Permits. Applications are reviewed by the various agencies from the context of

the approved EIR (or EIS). Five months are assumed required, but hopefully this review can be conducted in parallel with exploratory drilling operations such that operations are not delayed.

(3) Plant Siting and Certification Review (NOI and AFC Process). Utilities are required to file a "notice of intent" to construct a new power plant with the responsible federal and state agencies. The review process establishes the "need" for the plant and environmental acceptability of the site and plant design. It is assumed that this review can be accomplished in 18 months providing there is close cooperation between the responsible agencies beginning with the exploration EIR or EIS.

In summary, it takes approximately 8.5 years to get the first plant on line on private lands and 9.5 years on federal lands as is indicated in Figures 2-11 and 2-12. If adequate environmental baseline data are available, the development/approval process can be shortened by one year. Figure B-2 shows the assumed schedule used in defining development requirements for the development of a 200 MW_e site for a new prospect. It shows that after the first 50 MW_e, the additional plants are assumed to be brought on line on a minimum of two year intervals.

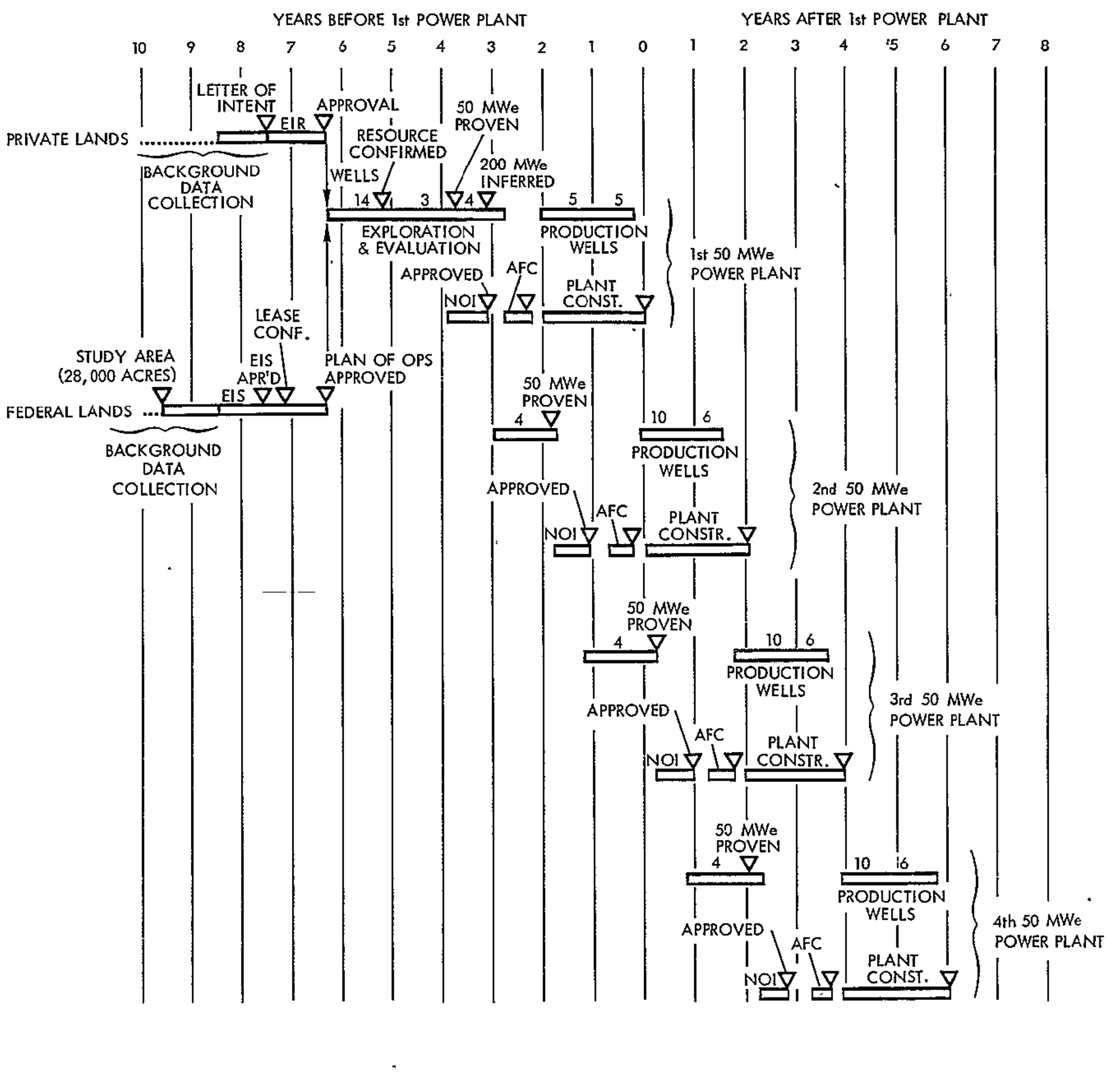

Figure B-2. 200 MW_e Site Development Schedule Assumptions

APPENDIX C

ADVISORY PANEL MEMBERSHIP

APPENDIX C

ADVISORY PANEL MEMBERSHIP

Three advisory panels were established to provide guidance and review of the JPL effort. They participated primarily in the critique of early scenarios and in providing insight into the many critical issues facing geothermal energy development in the state. The contributions of the panel membership should be recognized.

GOVERNMENT ADVISORY PANEL

Susan J. Brown*
State of California
Office of Planning and Research

John L. Dutcher
California Public Utilities Commission

Gerald E. Gould
Mining and Mineral Specialist
U.S. Forest Service

John Moon
Mineral Specialist
Bureau of Land Management

Robert Scott
Regional Hydrologist
Environmental Protection Agency

Mel Schrecongost*
California Department of Conservation

Reid T. Stone
Area Geothermal Supervisor
Conservation Division
U.S. Geological Survey

James H. Taylor
U.S. Geological Survey

Gil Torres
Associate Engineering Geologist
State Water Resources Control Board

*Now with the State Energy Commission

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Phillips Petroleum Company

Harry W. Falk, Jr.
Magma Power Company

Robert Grieder
Chevron Oil Company

Ben Holt
The Ben Holt Co.

David Howell
Republic Geothermal Inc.

Norman Ingraham
Norther California Power Agency

Dr. Paul Kruger
Stanford University

Joseph G. Meyer
Pacific Gas and Electric

Dr. Carel Otte
Vice President and Manager of Geothermal Division
Union Oil Company

Craig Racine*
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Vasel W. Roberts
Electric Power Research Institute

Herb Rogers
Rogers Engineering Company

Vane E. Suter
Union Oil Company

C. M. Swinney
Southern California Edison Co.

R. Bruce Williams
Pacific Gas and Electric

---

*Now with the Ben Holt Company.

ENVIRONMENTAL ADVISORY PANEL

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California Citizen Action Group

Spencer Amend
Regional Director
U.S. Fish and Wildlife Service

Max Crittenden
Chairman, GEAP
U.S. Geological Survey

Richard T. Forester
California Department of Fish and Game

Ronald Friesen
Senior Air Resources Engineer
Air Resources Board

Bob Giacosie
California State University, Dominguez Hills

Willard D. Hansen
County of Lake

Carl Harper
Lake County Energy Council

Hamilton Hess
Sierra Club

Donald F. Johnson
County Planner
County of Lake

Don Lollock
Chief, Environmental Services
Department of Fish and Game

Sal Lucania
Lake County Energy Council

Mike Pasqualetti
Department of Earth Sciences
U.C. Riverside

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